BBC

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Master the settings to take your best astro images yet

#192 MAY 2021

Sky at Night

THE UK'S BEST SELLING ASTRONOMY MAGAZINE

A NIGHT ON THE COAST

Discover a new perspective on the night sky down at the seashore

MERCURY'S CRESCENT

Can you spot surface shading on the smallest planet?

LIKE SUGAR ON BLACK VELVET

A guide to observing the season's most captivating globular clusters

7 STEPS TO A HABITABLE PLANET

Key features of planet Earth that could steer the search for alien life

THE GREAT DEBATE

The public talk 100 years ago that transformed cosmology

WINCHCOMBE METEOR

The historic find's trip from driveway to lab

COSMIC SPRING CLEAN

Solving the riddle of the missing space dust

MAKE AN ECLIPSE MODEL

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Welcome

Discover why the UK's coast is so appealing for stargazing

As an island nation, the UK has almost 17,820km of mainland coastline (according to the Ordnance Survey), which rises to 31,370km when you include its hundreds of islands. When you consider its surface area that's pretty high, and in fact the UK's is the 12th longest coastline globally.

Our seashore is also a region that has a special appeal to stargazers and astro imagers for many reasons, chief among them being big open views that extend unhindered low to the horizon. In this month's issue, on **page 28** Will Gater is your guide to observing from coastal settings, revealing expert tips on how to observe from public areas responsibly, and the objects that are brought out at their best by a sea view.

Whatever your observing location, spring is a great time to track down one scintillating class of deep-sky object: globular clusters. These concentrations of ancient stars located at the outer edges of the Milky Way and most other large galaxies, look great through any size of telescope and are richly rewarding to view at high magnifications, when individual stars begin to become apparent. Globulars are a favourite of Canadian astronomer Ron Brecher, and his feature on **page 34** will suggest some of the best examples to observe and image this season.

If you do decide to capture photos of the globular clusters you've tracked down, you'll find Charlotte Daniels's feature on **page 60** invaluable. Her beginner's guide to taking astrophotos with a DSLR camera details why these cameras are well suited to capturing images of deep-sky objects like globulars and many other night-sky favourites, as well as the best settings and accessories to use them with.

Clear skies, and enjoy the issue!

Chris Bramley, Editor

PS Our next issue goes on sale on Thursday 20 May.

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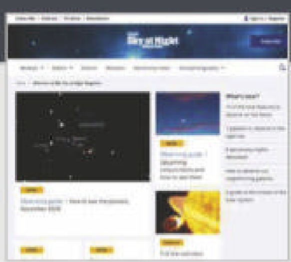
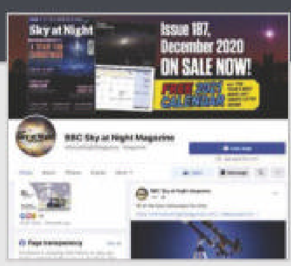
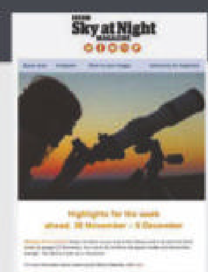
Sky at Night – lots of ways to enjoy the night sky...







Television
Find out what *The Sky at Night* team have been exploring in recent and past episodes on page 18

Online
Visit our website for competitions, astrophoto galleries, observing guides and more

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The best targets to observe each week, delivered to your inbox. Visit **bit.ly/skynewsletter**

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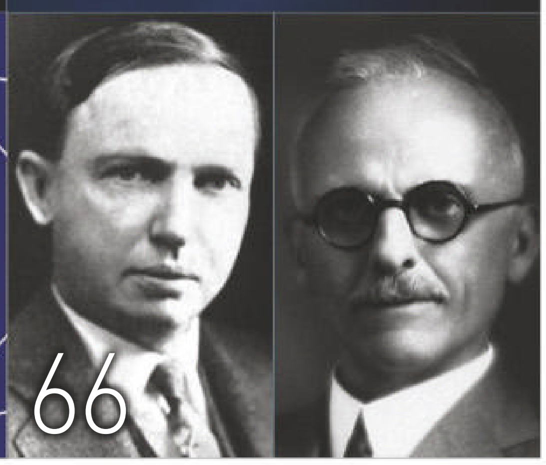
COVER MAIN IMAGE: SHAIITH/ISTOCK/GETTY IMAGES. THIS PAGE: SCHROPTSCHOP/ISTOCK/GETTY IMAGES, RON BRECHER, WILL GATER, CANON, SON OF ALAN FOLIO, @THESHED_PHOTOSTUDIO

New to astronomy?

To get started, check out our guides and glossary at **www.skyatnightmagazine.com/astronomy-for-beginners**



This month's contributors

Ron Brecher

Deep-sky observer

"Globular clusters are among my favourite objects to view through the eyepiece and to image, which made it fun to write this article highlighting some of the most striking examples." **Ron picks the year's best globulars,** **page 34**

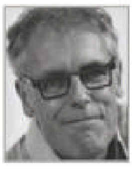
Charlotte Daniels

Astrophotographer

"DSLR cameras are a great option for astro imaging; get to know their features and settings and you can be capturing beautiful images of the night sky in no time". **Charlotte goes back to basics with DSLRs,** **page 60**

Govert Schilling

Astonomy journalist



"Working on the Great Debate story made me realise the enormous progress astronomers have made in our understanding of the Universe in one century." **Govert introduces the key figures in 1920's Great Debate,** **page 66**

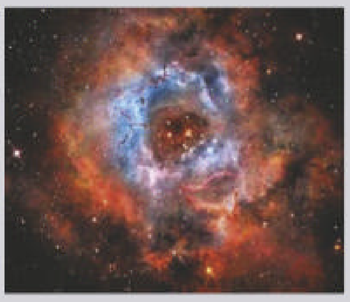
Extra content ONLINE

Visit **www.skyatnightmagazine.com/bonus-content/ZEUVFVV/** to access this month's selection of exclusive Bonus Content

MAY HIGHLIGHTS

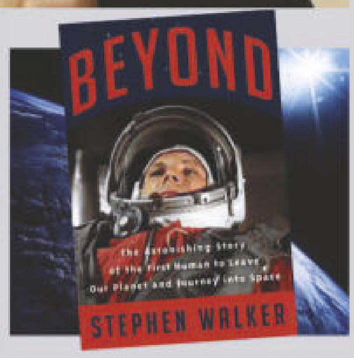
Interview: Secrets of the Universe

Astrophysicist Chanda Prescod-Weinstein discusses the important cosmic mysteries that have yet to be solved.



Astrophoto and space mission galleries

Beautiful images of the cosmos captured by *BBC Sky at Night Magazine* readers, robotic probes and space telescopes.



Audiobook preview: *Beyond*

Download and listen to a chapter from a new book detailing cosmonaut Yuri Gagarin's historic journey into space.

The Virtual Planetarium

Pete Lawrence and Paul Abel guide us through the best sights to see in the night sky this month.

A STAR IS BORN AGAIN (BRIEFLY)

Rare planetary nebula Abell 78 glows as it reawakens as a so-called 'born again' star

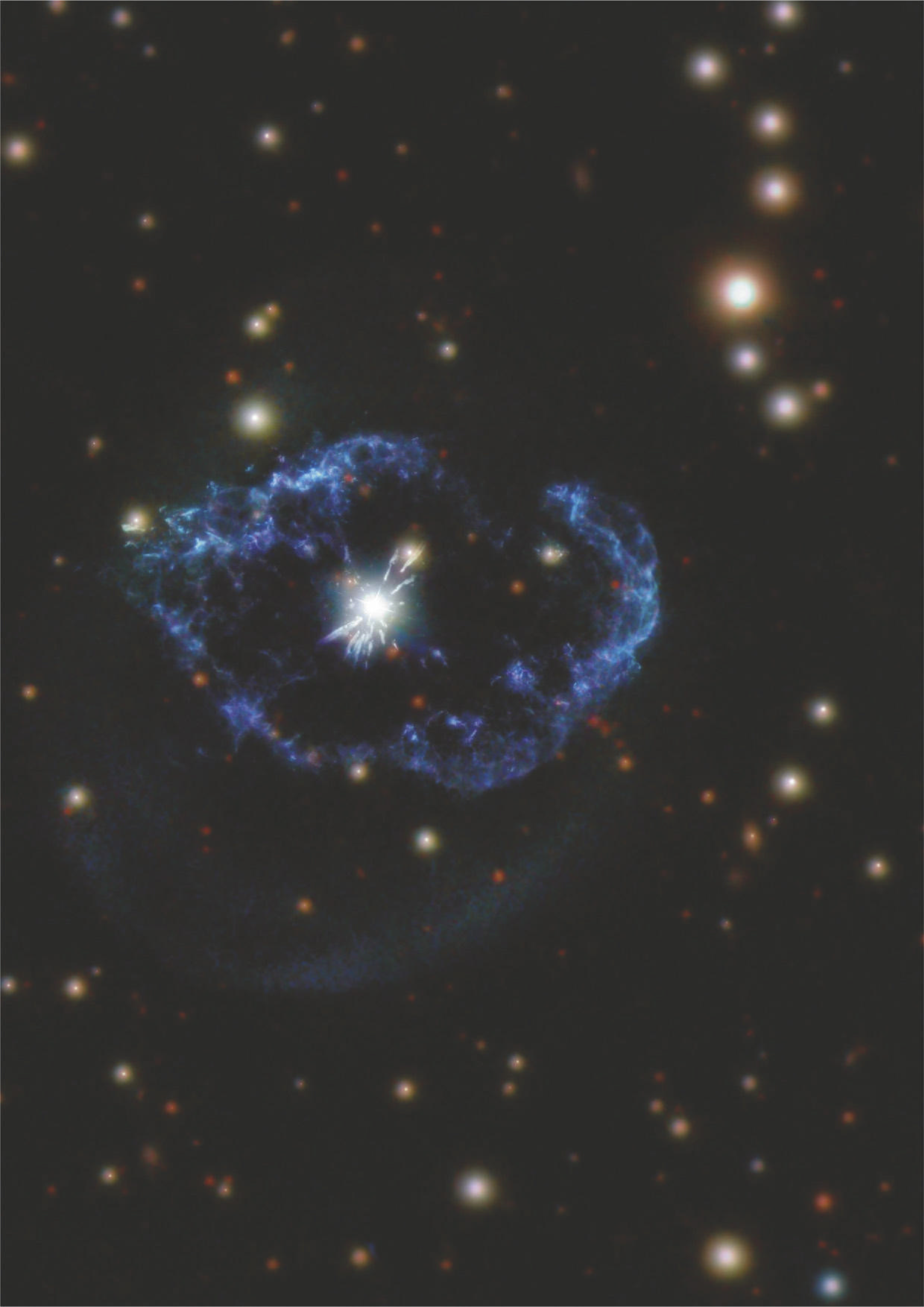
ESA/HUBBLE & NASA/M. GUERRERO. ACKNOWLEDGEMENT: JUDY SCHMIDT

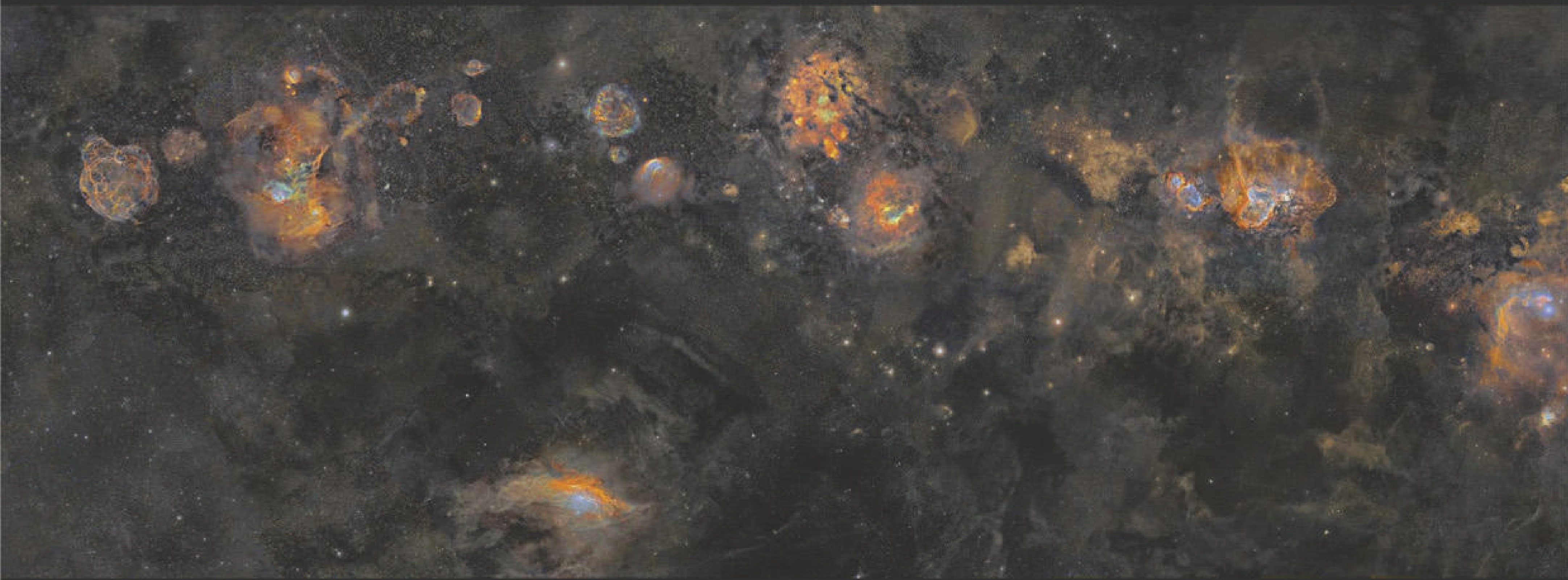
HUBBLE SPACE TELESCOPE & PAN-STARRS, 15 MARCH 2021

We can't blame William Herschel, who first coined the term in the 1780s, but 'planetary nebula' is a confusing misnomer. They have nothing to do with planets, but as he had recently also discovered Uranus (which he initially called a comet and a 'nebulous star'), it's understandable that Herschel conflated these hazy, disc-like objects with gas giant planets.

Planetary nebulae, like the Crab and the Dumbbell, are in fact the death throes of a star which, having exhausted the nuclear fuel at its core, collapses. Its shrugged-off outer layers create a diffuse gas shell, lit from within by a newly formed white dwarf.

Abell 78, however, is unusual. Found 5,000 lightyears away in Cygnus, it's a rare 'born-again' planetary nebula. While it has a hydrogen-poor centre, the blue filaments show that hydrogen is so dense in its outer layers that nuclear fusion has fleetingly restarted – the final gasp of the dying star.

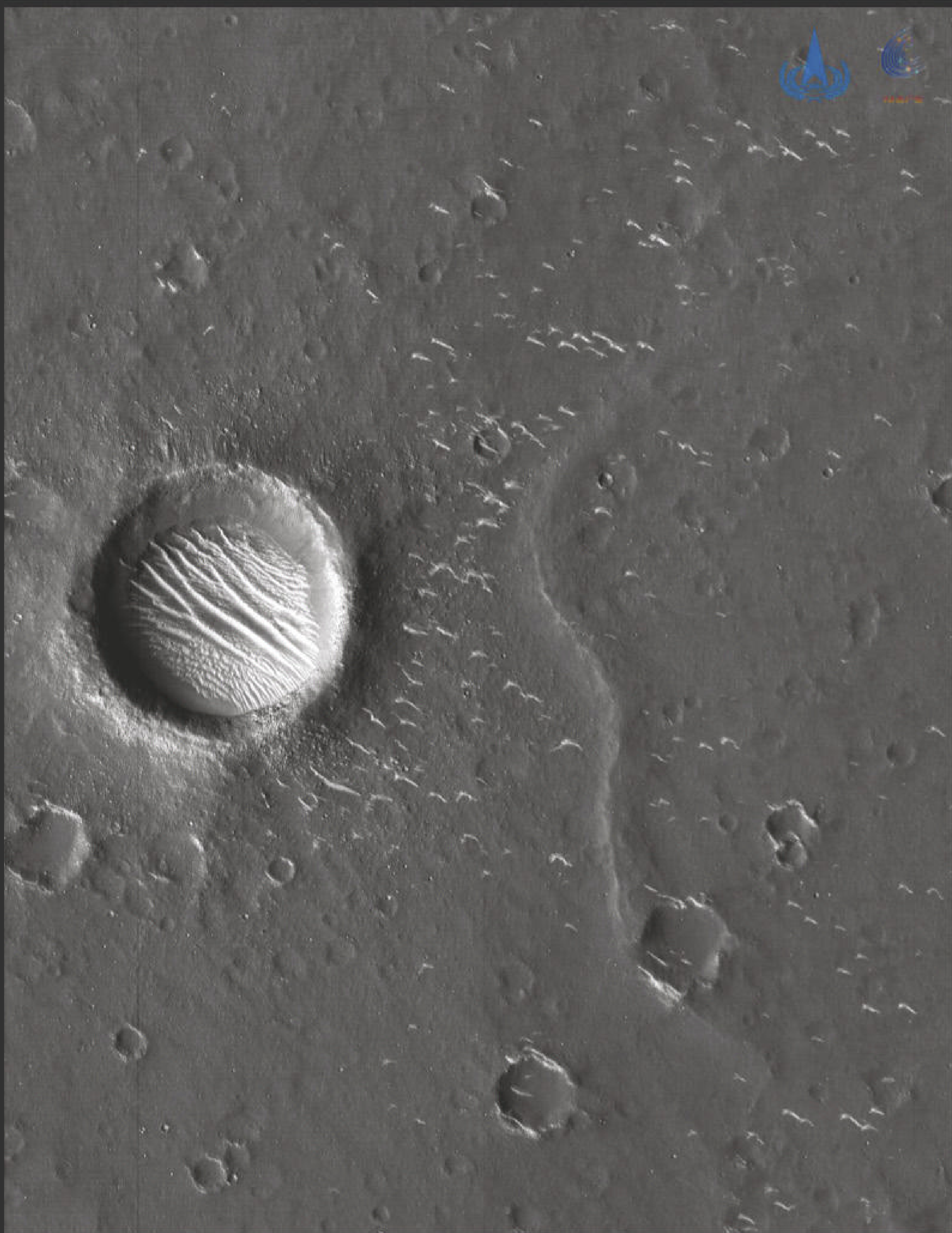




△ Milky Way mega-mosaic

J-P METSAVAINIO, MARCH 2021

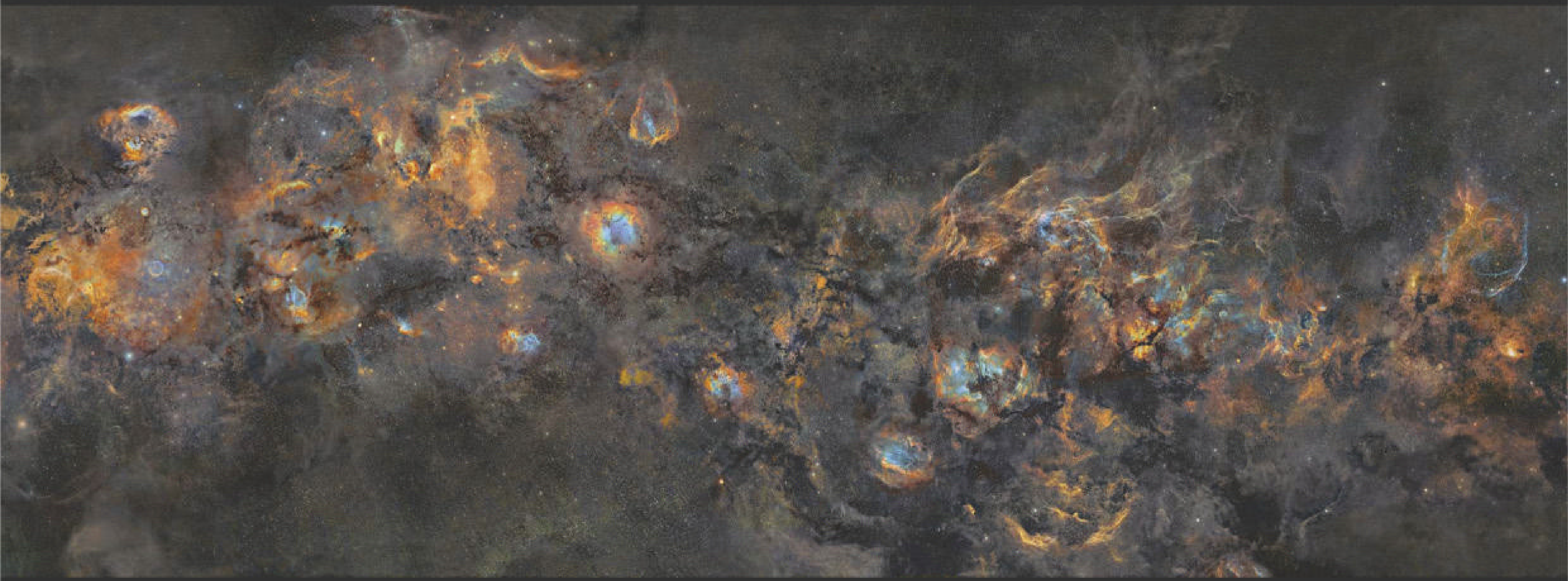
This extraordinary 234-panel high-resolution mosaic of the Milky Way was started by Finnish visual artist and astrophotographer J-P Metsavainio in 2009 and took almost 12 years to complete. About 100,000 pixels wide and capturing 125° of sky from the constellations of Taurus, the Bull (left) to Cygnus, the Swan (right), it shows an estimated 20 million individual stars. This Herculean effort called for over 1,250 hours of exposure time, including 100–plus hours on some of the dimmest supernova remnants.



Looking for a parking spot ▷

TIANWEN-1, 4 MARCH 2021

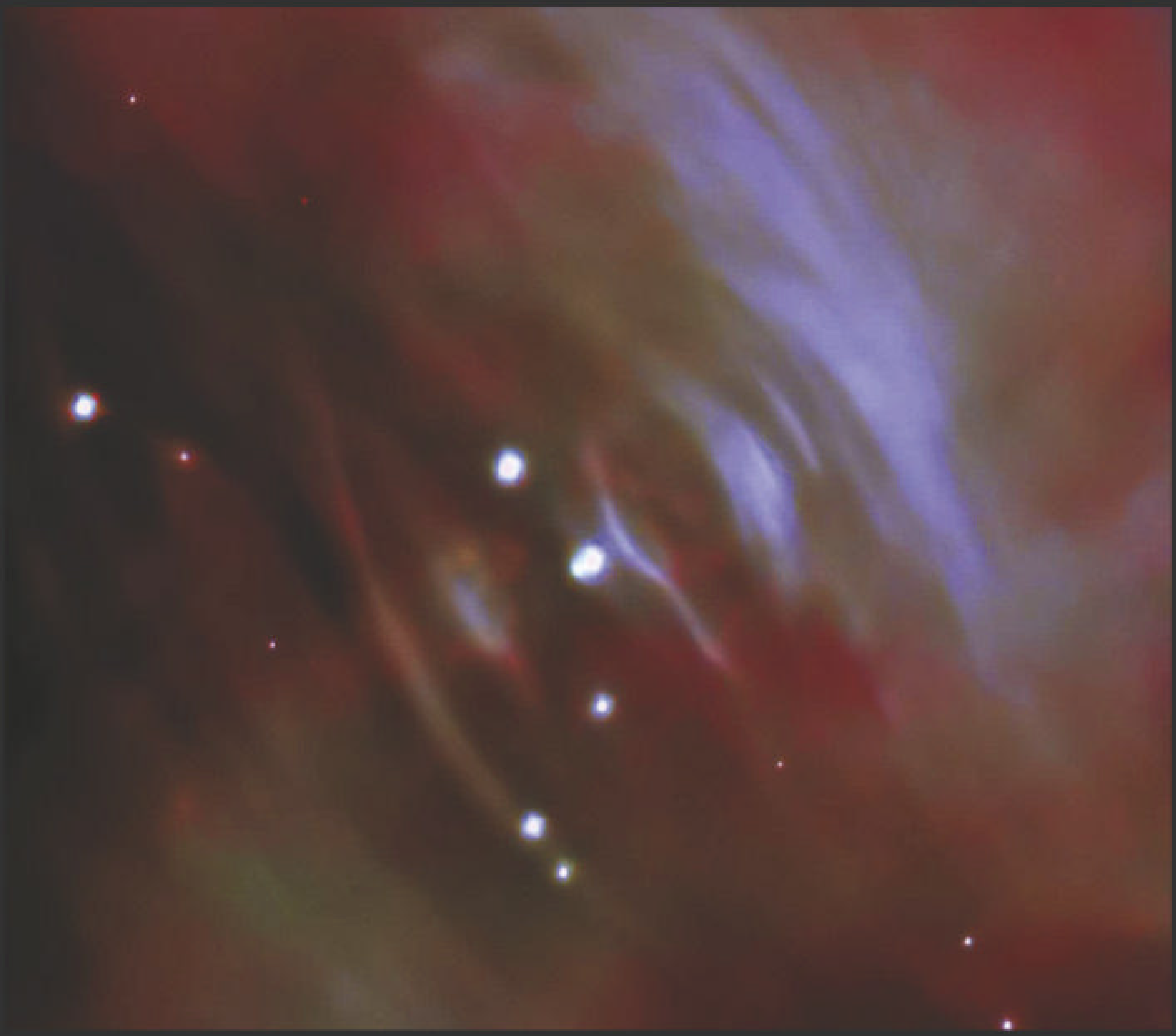
This is one of the first high-definition pictures returned by China's Tianwen-1 robotic probe. Currently in orbit above Mars, its seven mission payloads are performing scientific tasks and analysing the surface for potential landing sites for its landing capsule. The capsule is due to be deployed this month, becoming the sixth rover to ever land on the Red Planet (after Sojourner, Opportunity, Spirit, Curiosity and Perseverance).



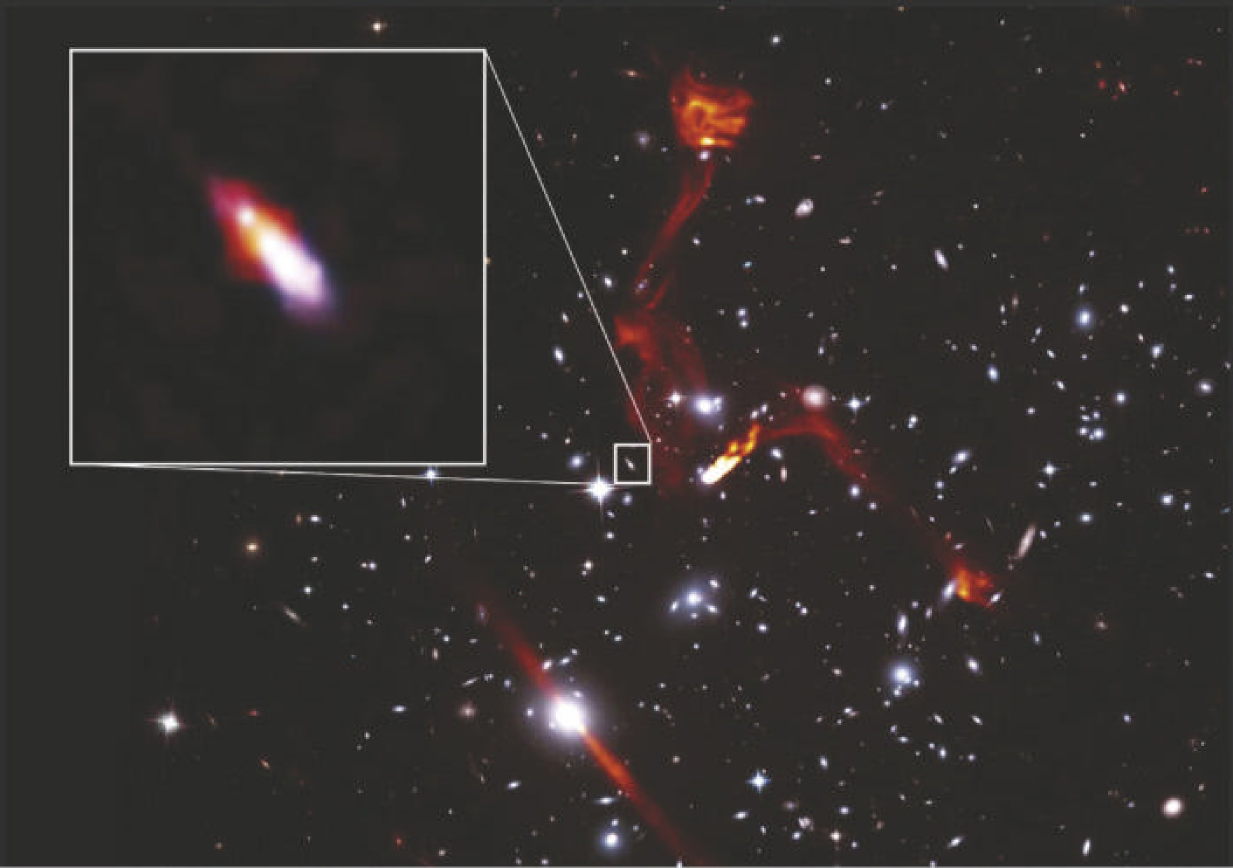
Beating heart of the Crab ▷

GEMINI NORTH TELESCOPE, 18 MARCH 2021

The Crab Nebula – remnants of a colossal supernova witnessed shining brightly for a month in AD 1054 – has a pulsing heart that creates the 'ripples' seen in this new image from Hawaii's Gemini North Telescope. The rapidly spinning, ultra-dense core of the exploded star, the pulsar throws out high-energy radiation that produces these visible shock waves as it slams into the surrounding nebula.



MORE ONLINE
A gallery of these and more stunning space images



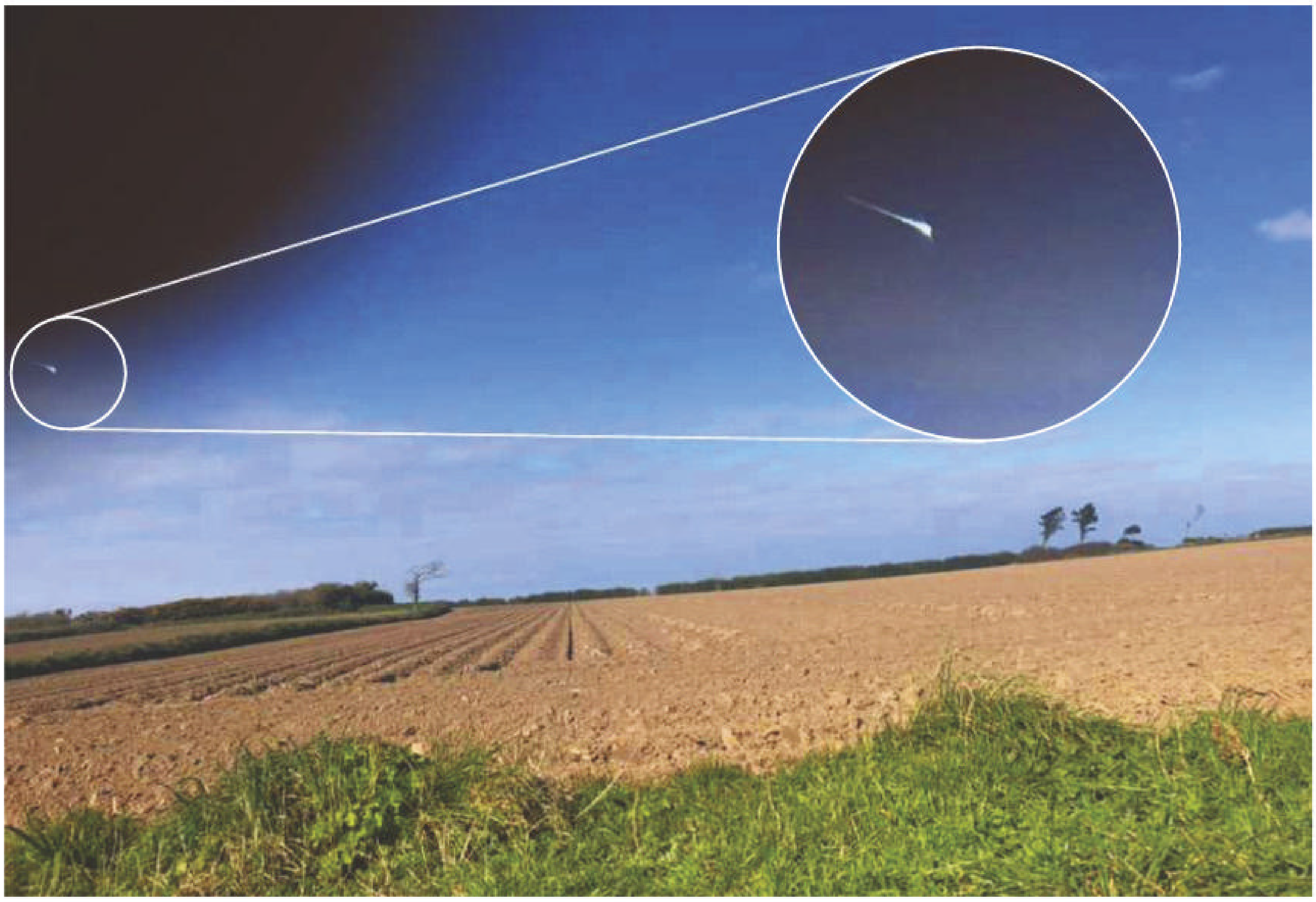
◁ Radio far far

VERY LARGE ARRAY, HUBBLE SPACE TELESCOPE, 16 MARCH 2021

Granted, VLAHFF-J071736.66+374506.4 doesn't trip off the tongue, but it's perhaps worth learning as an answer to a trivia question: What is likely to be the faintest radio-emitting object ever detected? Over 8 billion lightyears distant, the galaxy is seen here (pullout) – thanks to the magnifying effect of gravitational lensing – within the already far-flung galaxy cluster MACSJ0717.5+3745, 5 billion lightyears away.

The latest astronomy and space news, written by Ezzy Pearson

BULLETIN



▲ Daytime spectacle: a remarkable image captures a meteor (inset) streaking across Jersey's sky

Daylight fireball shoots over UK

The meteor on 20 March was the second large fireball seen in British skies within a month, though the two sightings are unrelated

A bright meteor, known as a fireball, streaked through the skies over the west of the UK on 20 March. The meteor was first reported just before 15:00 UT, when people in France, England, Wales and Jersey heard a 'sonic boom'. Some also saw a bright flash. The Ministry of Defence discounted an RAF aircraft, leading people to wonder if this could have been a rare event – a meteor bright enough to be seen during the day and which could have dropped meteorites.

Internet sleuths and meteor watchers alike quickly set about tracking down corroborating evidence, including *BBC Sky at Night Magazine* regular contributor Will Gater. "I went through each area of satellite imagery for the South West, scrolling back and forth through the data around the time of the sonic boom reports," says Gater. "In the data at 14:50 UT, there was this bright feature. I couldn't believe it, I had chills at the thought of what it might be."

The final confirmation of a meteor came when dashcam footage from Jersey showed a bright light streaking across the sky. The meteor was large enough and bright enough that it could have dropped meteorites. "At the moment we can only give rough guidance," says Ashley King from the Natural History Museum,"that there could be a meteorite on the ground somewhere between Verwood in Dorset and Romsey in Hampshire or a few miles either side of the line between them."

The meteor was spotted just two weeks after freshly fallen space rocks were recovered from Winchcombe, Gloucestershire, and its surrounding area. Could a second meteorite recovery be on its way? **www.ukfall.org.uk**

▸ **Turn to 'Inside the Sky at Night' on page 18 for more about the Winchcombe meteorite**

Comment

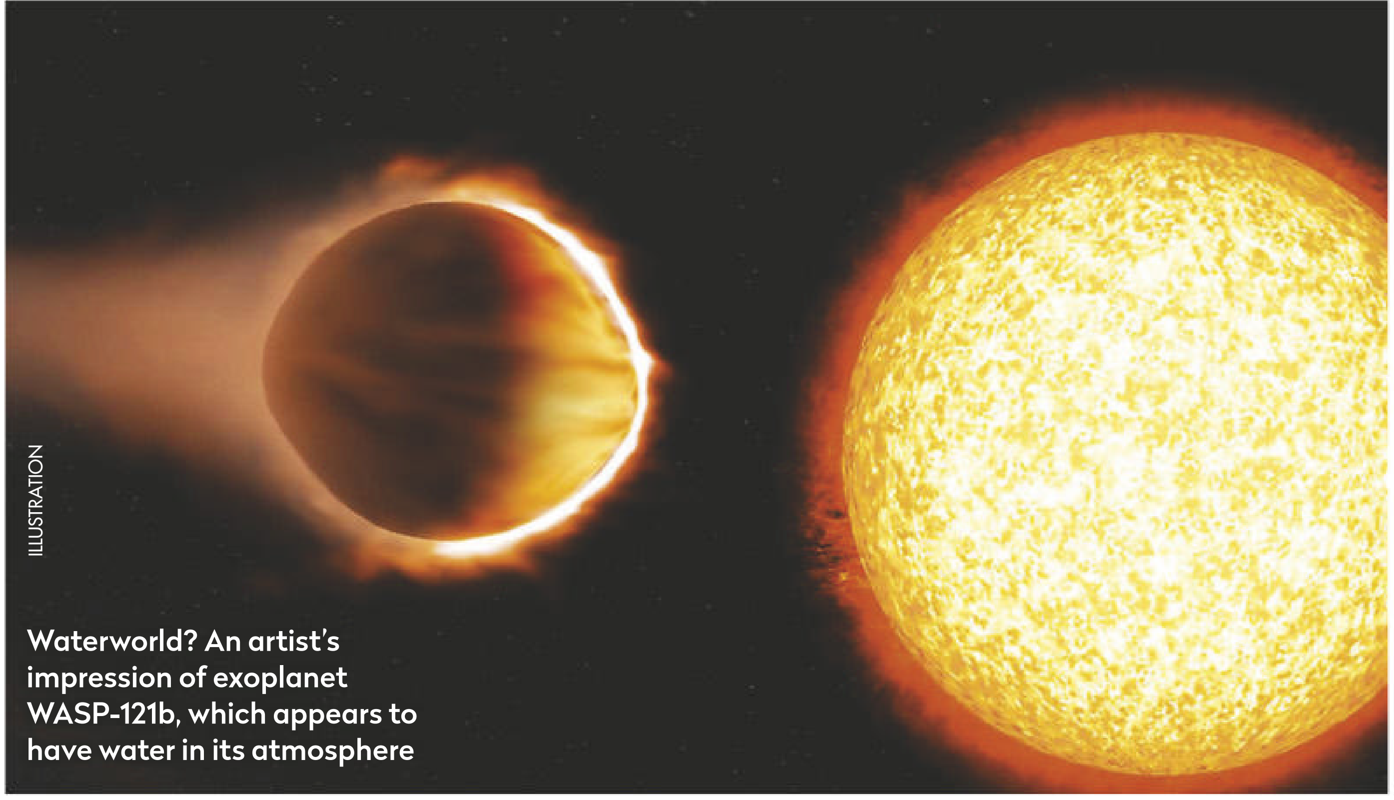
by Chris Lintott

Seeing a fireball is special – but meteorites are magic. Beyond the rich scientific yield we get, they provide an unusually physical connection to the cosmos above.

I became an astronomer because I love staring at the night sky and wondering what else might be there. To touch a meteorite gives me the same feeling.

Of course, not all meteorites are equal. Talking to the scientists who are working on the Winchcombe meteorite for the TV show this month was brilliant, but I'll never forget picking up a tiny vial with something that was in orbit about the Sun a couple of weeks before. It may have looked like a left over stock cube, but it will be a moment I'll treasure for ever.

Chris Lintott co-presents *The Sky at Night*



Waterworld? An artist's impression of exoplanet WASP-121b, which appears to have water in its atmosphere

Water-rich atmospheres could be common

Exoplanets might retain a humid atmosphere for billions of years

Planets surrounded by water-rich atmospheres could be common throughout our Galaxy. A new set of simulations looked at mini-Neptunes, a group of planets which we now know are common despite having none within our Solar System. "We don't know for sure what they are made of, but there's strong evidence they are magma balls cloaked in a hydrogen atmosphere," says Edwin Kite from the University of Chicago, who led the study.

According to their investigation, the hydrogen would interact with oxygen in the molten rock to form water. Much of this would get locked up in the magma. Eventually, the stellar wind would strip away most of the planet's atmosphere, at which point the water would seep out of the rock as vapour, creating a humid environment which could last on some planets for billions of years.
www.uchicago.edu

Most distant jet seen shooting out of black hole

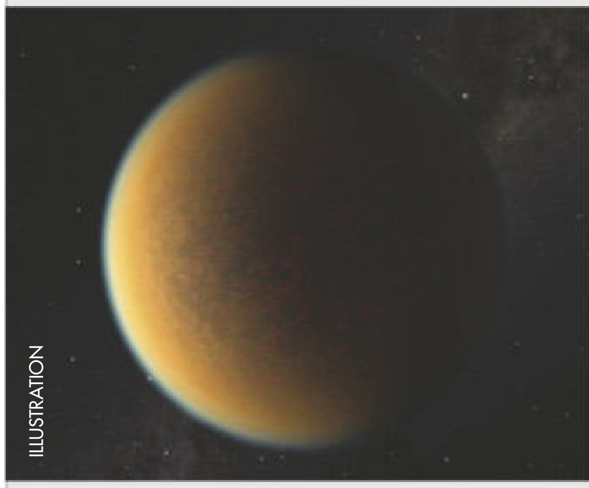
Ancient emission: the jet is 160,000 lightyears long

An enormous jet coming from a black hole just one billion years after the Big Bang has been found by the Chandra X-ray Observatory. This is the earliest known jet of its kind and could help us understand how such structures shape their host galaxies.

The jet comes from a quasar, a rapidly growing supermassive black hole surrounded by hot gas, called PJ352-15 15. It is 160,000 lightyears long – around 1.5 times the width of the Milky Way. These jets can help black holes to grow by removing energy from the swirling discs of dust that surround them. This slows the material down so that it falls onto the black hole, adding to its mass.

"The length of this jet is significant because it means that the supermassive black hole powering it has been growing for a considerable period of time," says Eduardo Bañados from Max Planck. "This result underscores how X-ray studies of distant quasars provide a critical way to study the growth of the most distant supermassive black holes."
https://chandra.si.edu

NEWS IN BRIEF



Distant volcanoes

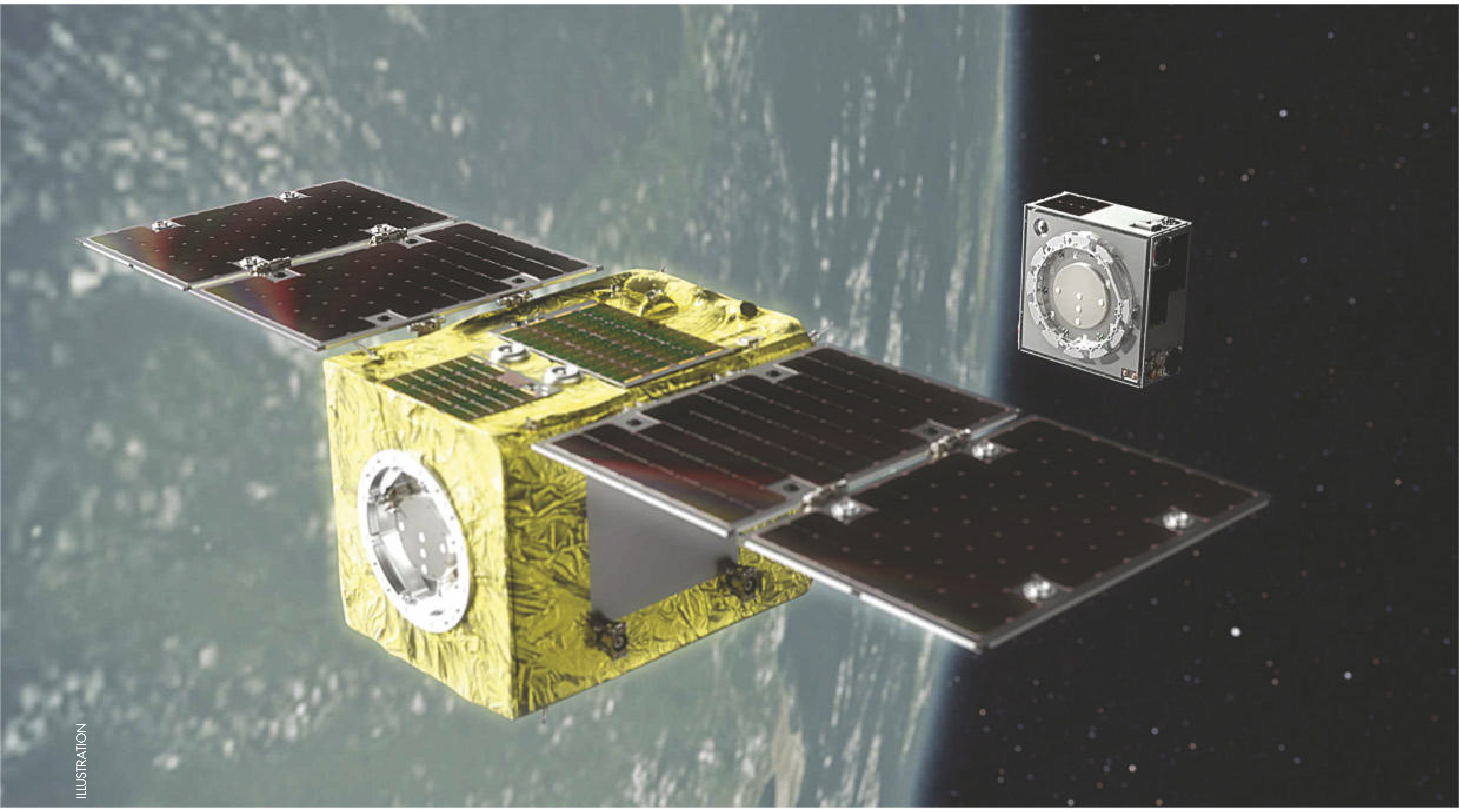
Hubble has spied the first evidence of volcanic activity reforming an atmosphere around a rocky exoplanet. The telescope spotted signs of hydrogen, hydrogen cyanide, methane and ammonia in the atmosphere, which would only be present if volcanic activity was pumping them out.

NASA gets new head

Former astronaut and democratic senator Bill Nelson has been nominated as NASA's next administrator. As well as flying on the Space Shuttle in 1986, Nelson was one of the political driving forces behind the development of the Space Launch System, which is being used in the Artemis Moon missions.

Missing mass tracked down

The Universe's missing 'ordinary' matter has been found hiding out in the far regions of galactic haloes. A novel study looked at how the unseen matter bends light from the early Universe to determine where the missing mass could be found.



▲ **Creating a clean space: the Elsa-d spacecraft will deploy a mini-sat to mimic a piece of space junk, which it will practise recapturing**

UK companies set to clean up space sector

A mission to clean up space junk and a cash injection are helping the UK industry to grow

March was a particularly good month for British spaceflight, seeing the launch of a prototype spacecraft that will one day clean space debris out of low-Earth orbit, while five British space companies received over £1 million of government funding to help foster international co-operation and innovation.

On 22 March, UK company, Astroscale, launched the Elsa-d (End-of-Life Service by Astroscale demonstration) spacecraft into orbit, the first step in a project to clean up some of the 9,000 tonnes of space debris around our planet. Elsa-d will deploy a 17kg 'client' mini-sat, which it will then recapture using its magnetic docking plate. To mimic space junk, the client will be sent into a tumble to see if it can still be recaptured under more trying conditions. If successful, the technology will be used to latch onto defunct satellites and deorbit them, clearing them out of low-Earth orbit.

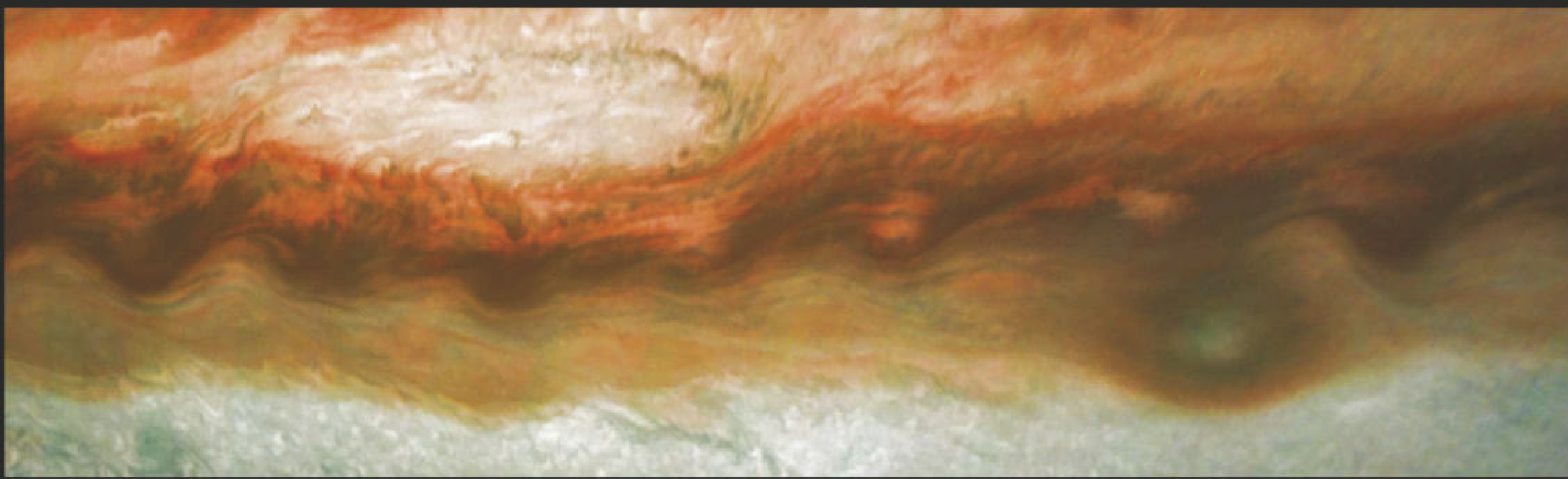
The launch came just a few days after the UK Space Agency announced that five new projects have received a total of over £1 million in funding from the government – including £85,000 to help identify and promote sustainable uses of outer space, like the Astroscale mission.

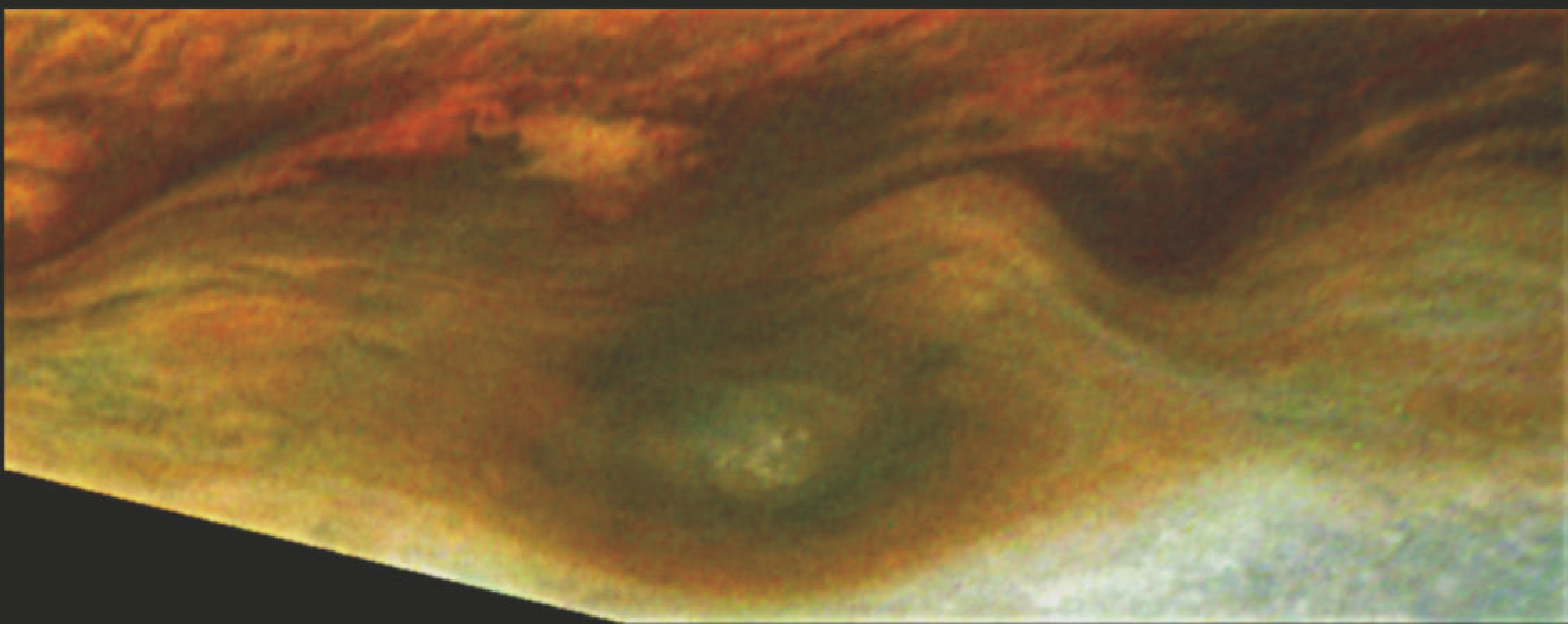
The move is part of a major drive by the UK Space Agency to promote British space industry, which has grown more than 60 per cent since 2010.

"Space technologies are part of almost every aspect of our daily lives," says Graham Turnock, chief executive of the UK Space Agency. "With rapid technological innovation, space offers a broad and growing range of opportunities to support economic activity and protect the environment. These projects champion the best of British innovation while strengthening worldwide partnerships."

The sustainable space project is in support of the efforts of the UN Office of Outer Space Affairs, while the other funds were given to UK companies working with international partners. These include: a collaboration with the Canadian Space Agency to investigate ice on the surface of Mars; an in-orbit service for tracking rockets with companies in Japan, France and the US; a system to forecast flooding in India; and a project to enhance UK-built camera technology that will be used by space missions, including NASA's future Nancy Grace Roman Space Telescope.
www.gov.uk/government/organisations/uk-space-agency

ASTROSCALE, AGU/JOURNAL OF GEOPHYSICAL RESEARCH: PLANETS





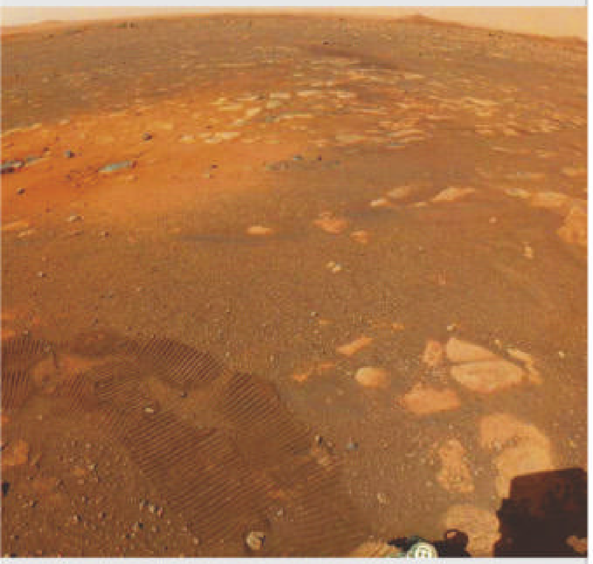
Great Red Spot snacks on smaller storms

As many as two dozen anticyclones buffeted Jupiter's Great Red Spot (GRS) back in 2019, and now a new examination has revealed many of the smaller storms were gobbled up by the mighty maelstrom.

The Great Red Spot has been seen on Jupiter for at least 150 years and consuming smaller storms could be one of the ways it manages to keep going for so long.

"The ingestion of [anticyclones] is not necessarily destructive; it can increase the GRS rotation speed, and perhaps over a longer period, maintain it in a steady state," says Agustín Sánchez-Lavega from Universidad del País Vasco, who led the study.

NEWS IN BRIEF



Perseverance on the move across Mars

NASA's Perseverance Mars rover made its first journey across the Martian surface on 4 March. As this was a test, it travelled only 6.5m. Meanwhile, Ingenuity – the drone-like scout onboard the rover – has finished its pre-flight checks and is expected to make its first flight in early April.

SLS test success

NASA's new heavy launch vehicle, the Space Launch System (SLS), successfully completed a static fire test of the rocket's engines on 18 March. A previous attempt in January shut down after just 67 seconds, but this run fired for a full eight minutes and 20 seconds.

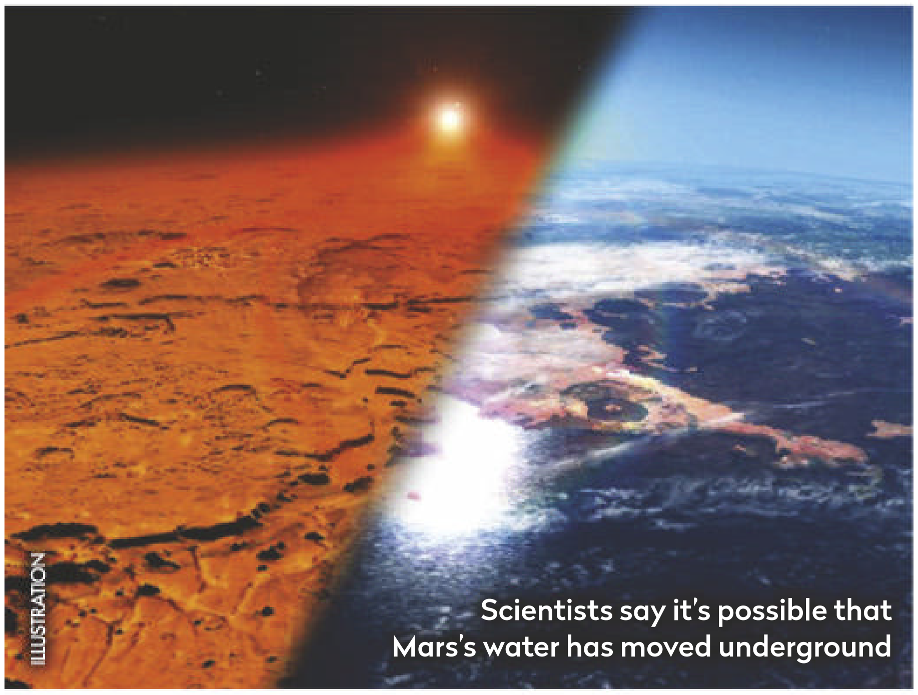
Aromatic clouds

A new reservoir of aromatic chemicals – complicated molecules which are important in forming life – has been found in clouds of cold dust. Previously it was thought these chemicals were primarily formed in stellar atmospheres, but these molecules were found in clouds without any stars.

BULLETIN

Mars probably didn't lose all its water to space

Other water loss mechanisms are likely to be at play



Scientists say it's possible that Mars's water has moved underground

A set of studies has cast new doubt over the idea that the Red Planet lost most of its past water to space.

One team looked at levels of a heavy version of hydrogen, called deuterium, on Mars. As lighter hydrogen more easily escapes the planet's gravity, if water was escaping the atmosphere there would be an excess of deuterium, but that doesn't match measurements.

Meanwhile, two other groups used ESA's Mars Express mission to measure the water in the Martian atmosphere over several years. Using those measurements, the teams estimated it would take a billion years for sea levels to drop by just 2m due to atmospheric water loss.

"As it hasn't all been lost to space, our results suggest that either this water has moved underground, or that water escape rates were far higher in the past," says Jean-Yves Chaufray from Laboratoire Atmospheres Observations Spatiales, France who led one of the studies.
https://sci.esa.int/web/mars-express

Study finds satellites increase sky glow

Light pollution across the world could have increased by as much as 10 per cent due to the growing number of satellites currently in orbit. The latest simulations show the background glow of the sky is increasing as more light is being scattered off objects that are in orbit.

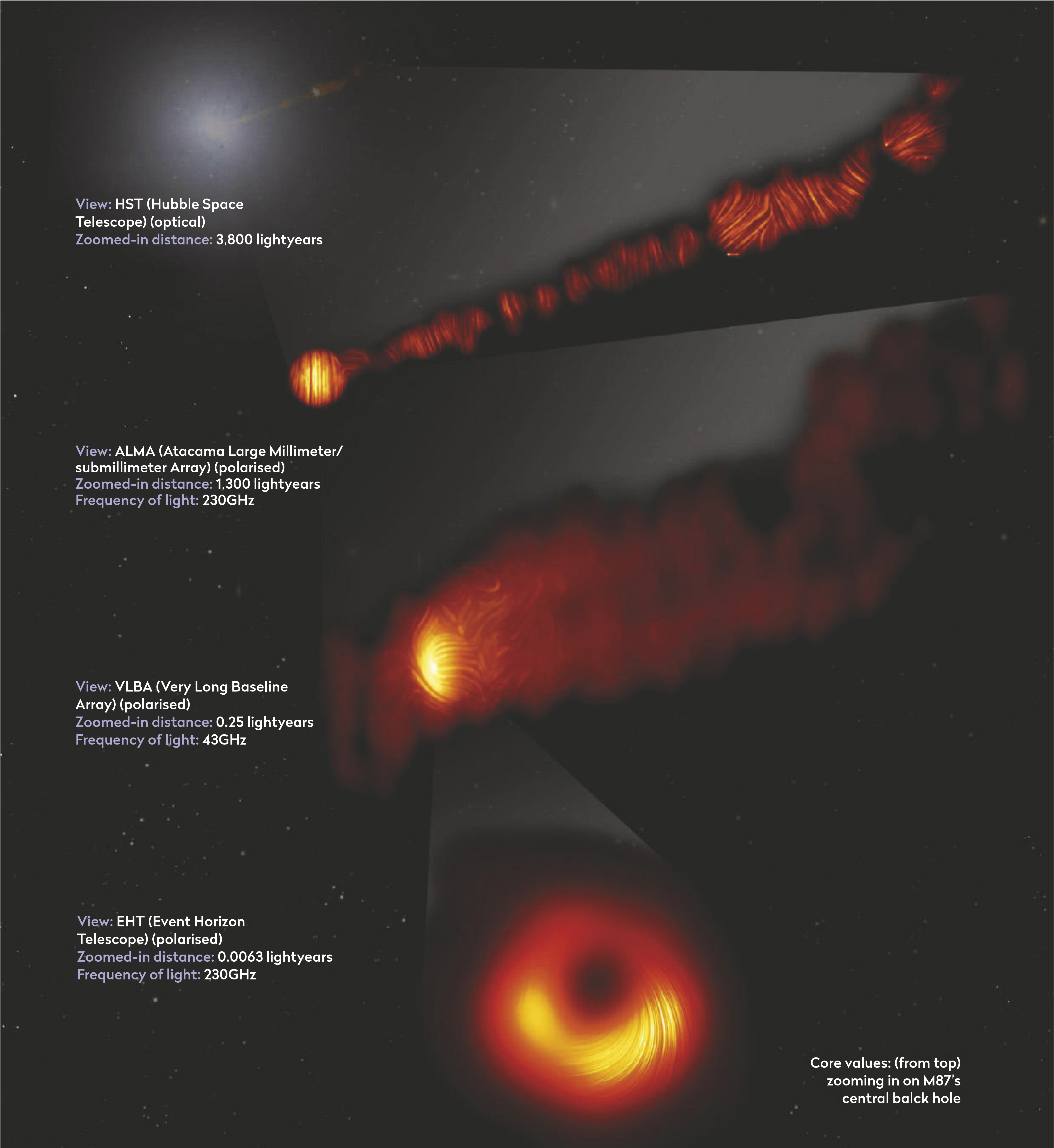
▲ What price progress? As more satellites are launched, the risk of light pollution increases

While the increase currently isn't noticeable with the naked eye, it will affect astronomers taking deep-sky images, though it may be possible to compensate.

"If it's uniform, it's okay," says Mireia Montes from the Space Telescope Science Institute. "You just end up putting more time in, and your images end up being more expensive."

Unfortunately, the problem is only set to get worse. The current estimate is based on the 1,000 Starlink communication satellites launched by SpaceX since 2019, but tens of thousands more have been licensed to fly in the coming years.

"It's a bit of an eye opener," says John Barentine, from the International Dark-Sky Association (IDA) who helped author the study. "As space gets more crowded, the magnitude of this effect will only be more, not less."
www.darksky.org



Core values: (from top) zooming in on M87's central balck hole

Image of M87's black hole updated

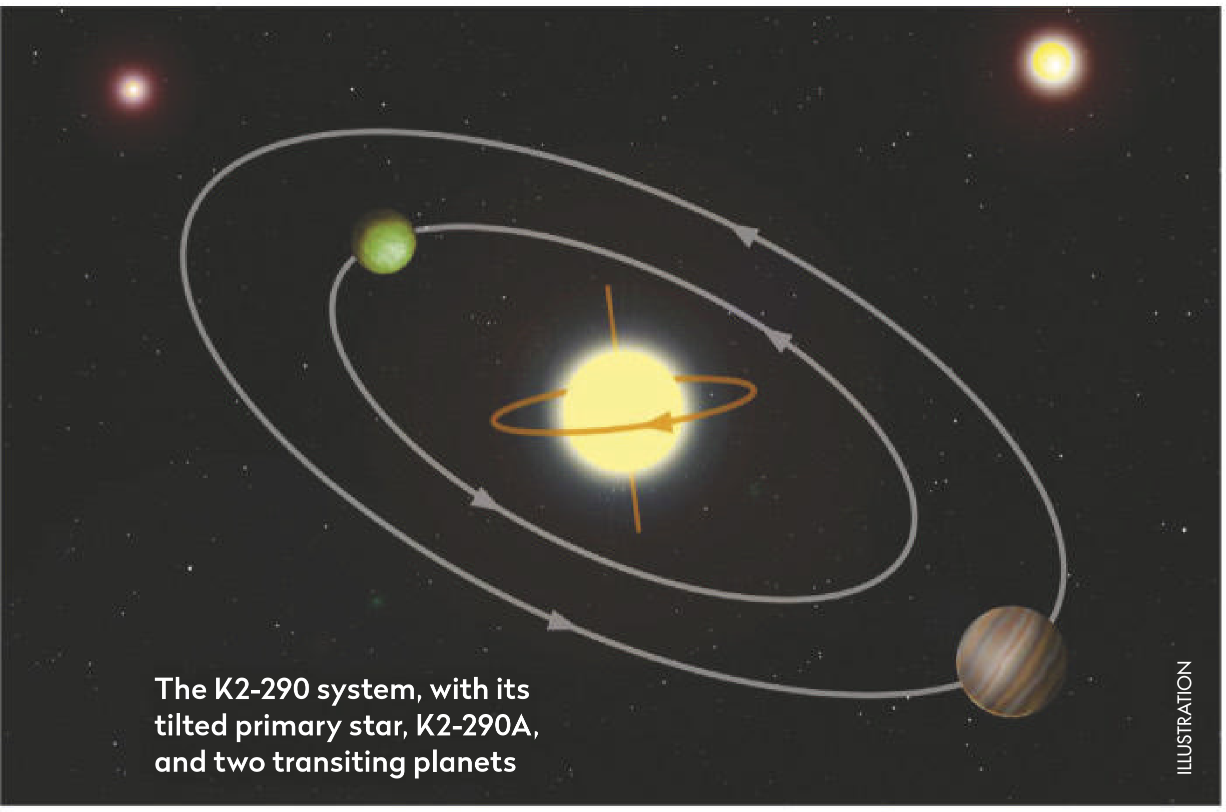
A new view of the black hole at the heart of galaxy M87 could help astronomers work out how it produces its colossal jet, which extends out over 5,000 lightyears from the central black hole.

M87's central singularity made history when it became the first ever black hole to be imaged in 2017, by a network of radio telescopes known as the Event Horizon Telescope. Since that first image was revealed to the public in 2019, astronomers have been examining the black hole's magnetic field in more detail. They did this by looking at the light's polarisation, as how the light is polarised is determined by the direction of the black hole's magnetic field when it was emitted.

"We are now seeing the next crucial pieces of evidence to understand how magnetic fields behave around black holes, and how activity in this compact region of space can drive powerful jets that extend far beyond the galaxy," says Monika Mościbrodzka, from the University of Valencia and coordinator of the EHT's Polarimetry Working Group.

Our experts examine the hottest new research

CUTTING EDGE


The K2-290 system, with its tilted primary star, K2-290A, and two transiting planets

ILLUSTRATION

Planets orbit around a backwards spinning star

A planetary system appears to have been pulled out of line by a neighbouring star

Our Solar System is nicely ordered. All the planets move around the Sun in more-or-less perfect circles, and all their orbits are aligned in the same plane – like marbles rolling around the same dinner plate. This is known as the plane of the ecliptic, and it's the reason why the Sun, the Moon and all the planets appear to move along the same narrow band in our skies – the zodiac. The Sun's own rotation is aligned in the same way (well, it has an axial tilt of just 7°) so that the solar equator lies along the plane of the ecliptic.

As a molecular cloud begins collapsing, the conservation of angular momentum ensures that newly-forming protostars become surrounded by a flattened disc of gas and dust that forms planets. And so the orderly layout of our own Solar System was also the way that any other planetary systems were expected to be arranged. But as we discovered more extrasolar planetary systems we realised how wrong this is: now we know of systems where the stellar equator and the planets' orbital plane are misaligned.


Prof Lewis Dartnell is an astrobiologist at the University of Westminster

Most of these distorted systems involve a singleton Hot Jupiter exoplanet. In these cases it's thought that during the gas giant's disruptive migration in towards its star, scattering other planets out of the system, the original orderly arrangement became distorted to leave a substantial tilt between the orbital plane and the plane of stellar rotation. In theory, misalignments between the central star and the entire planetary disc also ought to be possible from the gravitational meddling of a wide-orbiting companion star, but no convincing examples of this had ever been found.

A realignment of thinking

Until now, that is. Maria Hjorth and Simon Albrecht, both in the Department of Physics and Astronomy at Aarhus University, Denmark, have been looking for such systems – ones that became grossly misaligned before the planets had finished forming. The clearest evidence would be a system of multiple planets all orbiting within the same plane (like the Solar System), but with a backward rotating star. It's hard to see how this arrangement could be achieved by scattering planets after they'd formed, and so surely would bear testimony to an unbalancing during its earliest eras.

"The inner M-dwarf companion star is believed to have been responsible for tilting the plane of the entire protoplanetary disc as it formed"

Hjorth and Albrecht point to the K2-290 system as the first known example of such a major planetary realignment. The K2-290 system consists of three stars: the primary is an F-class star about 20 per cent more massive than the Sun, with an M-dwarf orbiting at around 113 AU, and another M-dwarf much further away at around 2,500 AU. The primary star, K2-290 A, is tilted by 124° relative to the orbits of both of its known planets. And the inner M-dwarf companion star is believed to have been responsible for tilting the plane of the entire protoplanetary disc as it formed.

In our Solar System we have Venus as a planet that rotates in the opposite direction – believed to be due to a colossal primordial collision that tipped it right over. The K2-290 A system presents us with a fascinating instance of the opposite: an entire planetary system tipped over relative to its star.

Lewis Dartnell was reading… *A backward-spinning star with two coplanar planets* by Maria Hjorth, Simon Albrecht et al.
Read it online at: https://arxiv.org/abs/2102.07677

SAKKMESTERKE/ISTOCK/GETTY IMAGES

Where is all the dust?

Stars pump out dust into the Universe, only for it to vanish from view over time

Prof Chris Lintott is an astrophysicist and co-presenter on *The Sky at Night*

Dust is everywhere in the Universe. It plays a crucial role in star formation, allowing material in stellar nurseries such as the Orion Nebula to cool enough that gravitational collapse is likely, and once that's done it forms the raw material for planets. On a larger scale, no attempt to observe or understand a distant galaxy – or our own Milky Way – can fail to take into account the effect of dust on what we see. A single dust grain may be tiny, no more than a tenth of the size of a sand grain, but the effects of dust as a whole are mighty.

As a result, much attention has been paid to how this cosmic dust forms, with the atmospheres of giant, cool stars likely to be responsible for most of it. The dramatic fading of Betelgeuse in the constellation of Orion, the Hunter more than a year ago, for example, seems to have been caused by the appearance of new dust in the star's tenuous outer atmosphere. Yet, relatively little attention has been paid to the other end of cosmic dust's life cycle. This month's paper does just that, working out how dust is destroyed.

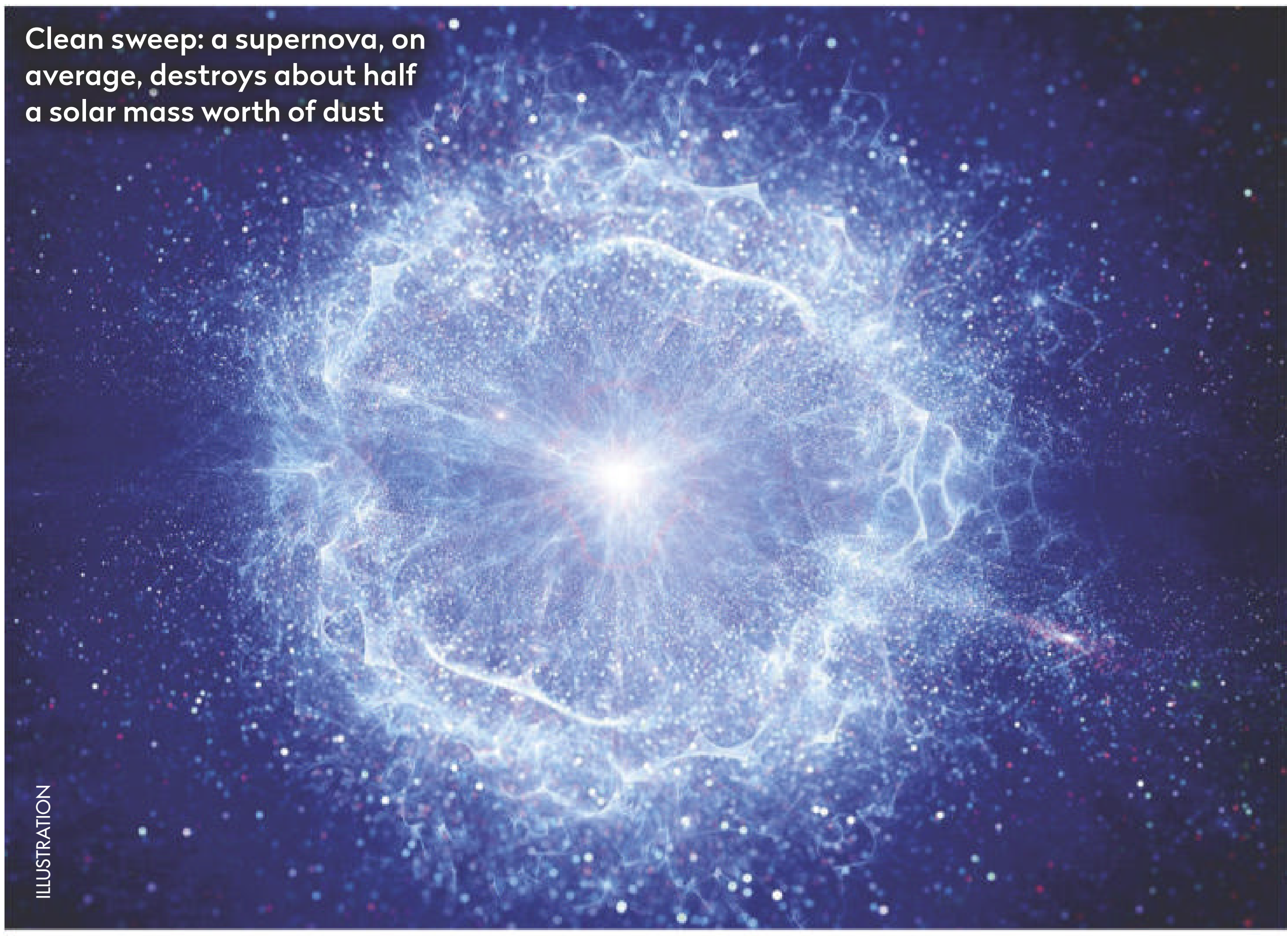
It's an important problem because we know, from looking at the dust content of galaxies, that the amount of dust in the Universe has been dropping for at least the last eight billion years or so. This is surprising as the amount of raw material for dust, in the form of carbon, silicon and the other heavy elements astronomers call 'metals', is increasing. Production is continuing apace and so something not accounted for in most models must be destroying the dust.

On the dust trail

Andrea Ferrara from Pisa and Céline Péroux from ESO (the European Organisation for Astronomical Research) in Garching think they have the answer – or rather answers. In their theory, about 40 per cent of the dust is destroyed by supernovae. It makes sense that powerful explosions which send shock waves through the cosmos might destroy delicate dust grains in the supernova's neighbourhood. But what's impressive about Ferrera and Péroux's idea is that they get significant loss of dust overall, while noting that each individual supernova might be less good at this than expected. The trouble is that massive stars which go on to produce supernovae tend to have powerful stellar winds, and these winds can sculpt a 'bubble' of material around them. Dust caught up in such a bubble forms a dense barrier, and it's therefore protected somewhat from the shock waves produced by the supernova. As a result, a supernova on average destroys about half a solar mass worth of dust – about a sixth of what less detailed modelling suggests. Given the supernova rate over the period studied, that's enough to account for 40 per cent of the dust loss we see.

"We know, from looking at the dust content of galaxies, that the amount of dust in the Universe has been dropping for the last eight billion years"

What happens to the rest? The answer is rooted in the fact that star formation requires dust. Dusty clouds can cool, and as they do so they collapse under their own gravity. The dust is not exempt from this process, becoming heated and incorporated into the star – a process rather wonderfully known as 'astration'. This process is efficient enough to account for the majority of lost dust in the last few billion years and explains why our Universe seems to be undergoing a long, slow spring clean.



Clean sweep: a supernova, on average, destroys about half a solar mass worth of dust

ILLUSTRATION

Chris Lintott was reading... *Late-time cosmic evolution of dust: solving the puzzle* by A Ferrara and C Péroux. **Read it online at: https://arxiv.org/abs/2103.06887**

INSIDE THE SKY AT NIGHT

▲ **Record delivery: the journey of the Winchcombe meteorite – from an asteroid to a laboratory – could be the fastest in history**

In April's episode of *The Sky at Night* the team met **Monica Grady**, one of the team analysing the meteorite recently found in Winchcombe

The Winchcombe meteorite was found after a lot of observations of a fireball on 28 February. Ashley King, who is a meteorite specialist at the Natural History Museum and helps the UK Fireball Network, went on local television and radio in Gloucestershire and alerted people, saying, "If anybody's got any unusual rocks that weren't there yesterday, send me a picture."

As a result we got loads of pictures, but there was only one that might have been a meteorite. That morning, a family had found this pile of grey dust spread out on their driveway with some bigger chunks sitting on top of it. They picked up the bigger bits using aluminum foil and put them in a sandwich bag. King asked my colleague Richard Greenwood if he could go have a look. And, yes, it was a meteorite, which is brilliant! I then started putting into action our recovery team along with colleagues from the Natural History Museum, as well as Imperial College London and the University of Manchester, but you can't just start wandering around people's fields and driveways in the time of a pandemic, so there was a lot of admin. Fortunately, everybody seemed to drop everything as they realised that this was something special.

Moving quickly

The meteorite was seen on Sunday, identified on Wednesday lunchtime, and by Thursday we had it in a mass spectrometer at the Open University. By Thursday night we had classified it. We reckon this is the fastest journey from an asteroid to a laboratory – certainly in UK history and possibly in global history – because it was collected and analysed so quickly.

There is some analysis that has to be done instantly: though the meteorite isn't radioactive it does contain some isotopes which decay on a very short timescale – a matter of days. Those can help us

Monica Grady is Professor of Planetary and Space Science at the Open University

calculate how big it was before it actually came through the atmosphere. There are a couple of other tests that need to be done quickly; because even though it's sitting in clean conditions, the longer it's on Earth, the more chance it will be contaminated.

There are also minerals which might lose their water and a lot of very volatile organic compounds – I haven't sniffed it yet, but my colleague said it smells like compost and that's those organic volatiles escaping. We usually lose those and don't get a chance to analyse them. After that, we'll take a chip of rock, embed it in resin and polish it to see what the surface looks like and what minerals are in there.

Meteorites come in two groups – primitive and processed. Primitive ones are made from dust left over from when the Solar System formed. Processed meteorites have been part of a planet at some point; these tell you about planetary cores and surfaces. The Winchcombe meteorite is a primitive meteorite, so it's unchanged since the dawn of the Solar System. It's a particularly exciting type because it's a carbonaceous chondrite. It's got lots of organic compounds in it, which are the stuff which eventually formed life. We're looking at a meteorite which contains the building blocks of life.

Words by Ezzy Pearson

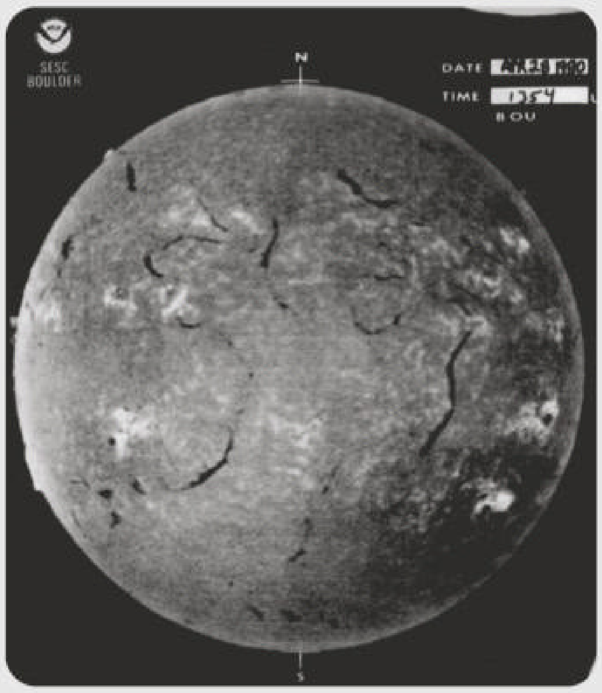
Looking back: The Sky at Night

18 May 1977

In May 1977, solar astronomers announced that a new solar cycle was beginning, the 21st since they started being recorded. The solar cycle is a measurement of how sunspot numbers rise and fall every 11 years, created by the motions of plasma deep within the Sun.

It takes several months of tracking to determine if the number of sunspots is increasing and to pin-point the precise timing of minimum activity, so while the announcement came in May 1977, the actual start of Solar Cycle 21 came in March 1976. Since then, the increase in the number of sunspots had been rather sluggish, as Patrick mentioned in that month's show. There was no cause for concern, however; when the maximum arrived in the early 1980s it ended up being more active than the previous cycle. Solar Cycle 21 lasted 10.5 years and ended in September 1986.

Since then, the number of sunspots has been decreasing with each cycle. But there's no need to worry – the drop off is thought to be a natural part of the Sun's fluctuations and solar activity will begin increasing again. What is not certain is whether our current cycle, Solar Cycle 25, will be the start of the upward trend or another low point.



▲ **Patrick Moore noted the slow start of Solar Cycle 21**

Mapping the Milky Way

The European Space Agency's Gaia spacecraft is producing a 3D map of the Milky Way. Mission scientists hope the results from the sky survey will help reveal the Galaxy's composition, formation and evolution. In this episode, Chris and Maggie look at what the mission has discovered so far, and what the latest results might reveal about our galactic neighbourhood.

BBC Four, **9 May**, 10pm (first repeat
BBC Four, **13 May,** 7:30pm)
Check www.bbc.co.uk/skyatnight for more up-to-date information

▲ **Gaia (inset) analysed over 1.8 billion stars to create a map of the entire sky**

Emails – Letters – Tweets – Facebook – Instagram – Kit questions

INTERACTIVE

Email us at **inbox@skyatnightmagazine.com**

MESSAGE OF THE MONTH

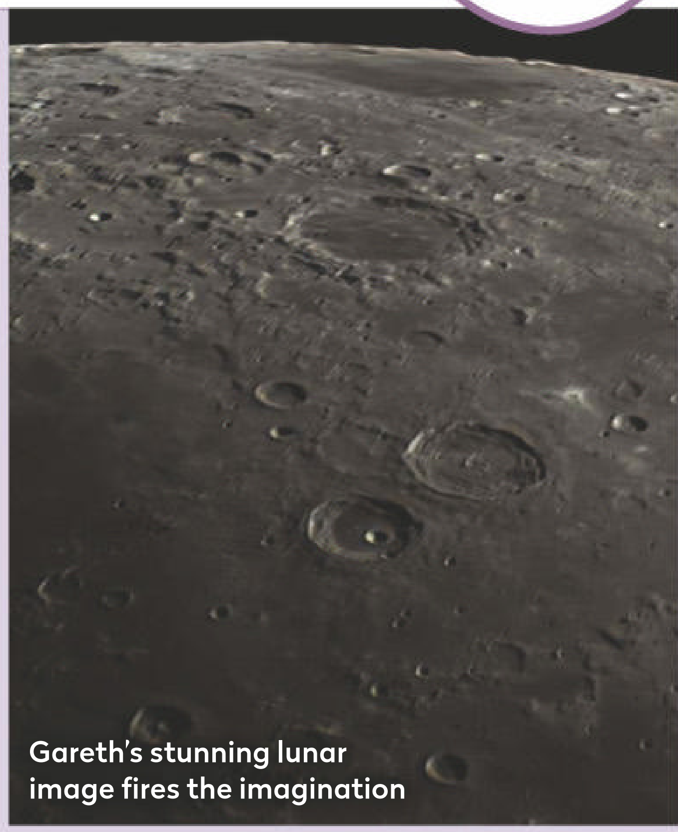
This month's top prize: four Philip's titles

PHILIP'S The 'Message of the Month' writer will receive a bundle of four top titles courtesy of astronomy publisher Philip's: Ian Ridpath and Wil Tirion's *Star Chart*, Robin Scagell's *Guide to the Northern Constellations*, Heather Couper and Nigel Henbest's *2021 Stargazing*, and a planisphere for the night skies as they appear at latitude 51.5° north.

Winner's details will be passed on to Octopus Publishing to fulfil the prize

Craters of the Moon

I started astro imaging last April as something to do during lockdown and was hooked. It continues to amaze me what can be observed and imaged in the night sky with very modest equipment. The 'Moonwatch' article in the February 2021 issue of the magazine (page 52) suggested Endymion as a target for the month, on either 14 or 15 February. I was unable to capture anything on those nights due to heavy cloud, but I captured this evocative image on the 16th with a Celestron C8-N telescope, Explore Scientific 3x Focal Extender and a ZWO ASI462MC camera, and processed the results with FireCapture, AutoStakkert!, RegiStax and Affinity Photo. With the craters Atlas and Hercules in the foreground, leading up to Endymion and then the Humboldtianum Basin on the limb, it makes me feel as though I am flying over the lunar surface. All it needs now is another moon, planet or Earth in the sky above!
Gareth Davies, Worcestershire


Gareth's stunning lunar image fires the imagination

What an evocative view, Gareth: looking at it you can imagine being an Apollo Command Module pilot orbiting the Moon alone while your two crewmates are exploring the lunar surface! **– *Ed***

Tweet

Jeff M
@jeffnmark • Mar 17
M81 in Ursa Major. About 2.5 hrs of 3-minute exposures, using a @zwoasi 533MC camera @ IM_SKYWATCHER 200PDS 8" telescope, EQ6r mount, ZWO 224 guide camera, controlled with an AsiAir. @skyatnightmag @AstroHour321 #pixinsight

A landmark aurora

Thank you for your article 'Chasing the Aurora' by Tom Kerrs (March 2021 issue, page 28). This rekindled memories of a boyhood conversation on the aurora borealis with my grandfather, Frederick Walter Mann (1905–98), who encouraged my early interest in astronomy. He recalled seeing the dramatic aurora of 25 January 1938, one of the rare occasions a display was visible across the whole of Great Britain as far south as Cornwall. He saw it from Barton Hill, the highest point near Bury St Edmunds in Suffolk, describing it as like, "A giant, moving red curtain stretching across the sky." According to Sir Patrick Moore, who described seeing it from Sussex in his book *The Amateur Astronomer* (1974), the predominant colour was red but, "I recorded many other hues as well." The display caused considerable interest and alarm across the country, including the fear among some people in southern England that the dramatic red glow filling the sky meant the whole of London was on fire.
Alan Murdie, Bournemouth

Keeping realistic

I enjoyed Jenny Winder's article on supermoons in the April issue (Explainer, page 72), where she highlights that they might not be so super to the untrained eye. I get annoyed with weather forecasters and newsreaders on TV overselling meteor showers, leaving the inexperienced viewer with the expectation that a shower of meteors is akin to those of raindrops in a rain shower.

To set expectations realistically I wish they would just say, "You might see a few meteors per hour in your light polluted skies from a low radiant with the sky washed out by the Moon". Setting too high expectations and getting people to

sit out in the cold only to be disappointed is not likely to encourage them to take further interest. I remember getting everyone to sit out one August night after a dinner party at the height of the Perseid meteor 'shower', only for the first 20 minutes to be totally devoid of a visible meteor. "I'm glad I didn't buy a ticket for this one," came a disillusioned voice from the back of the group.
Jeff Mason, Stockport

Garden Orion

Ever since I first became interested in astronomy, about 16 years ago, I have dreamed of having my own observatory so that I can have my Meade LX90 permanently set up and capture some deep-sky objects. In November last year my dream came true when I built myself a sliding roof observatory. My equipment is quite modest: a Canon DSLR, the aforementioned telescope and a laptop, but recently I had three – yes three – consecutive clear nights to capture the Orion Nebula, M42.

I was recently interested to see Charlotte Daniels's feature on processing nebulae in RawTherapee (January 2021 issue, page 78, Processing) and followed her guide to produce this picture (below). Thanks must go to my wonderful wife who gave up part of her beloved garden to my building project; I can now look forward to many more nights of astrophotography – clouds permitting of course.
Dave Elliott, Kirkby-in-Ashfield

Dave had three clear nights to capture M42

First name?

Nearly all the famous scientists, engineers and inventors that I've heard of are known by their surnames – Newton, Brunel etc. But why, ▸

ON FACEBOOK

WE ASKED: What are you most looking forward to when lockdown ends?

Carol Miller For the Lanivet Amateur Astronomers to get together on our meeting nights. Before last year's lockdown we were meeting once a month and, although our Facebook group has continued and has grown, I miss being with fellow amateur astronomers and sharing the excitement of seeing what's up in the night sky.

Susan Pilcher The Milky Way at Dungeness, I really can't wait!

Keith Moseley Solarsphere Astronomy/Music Festival 2022.

Rob Allen The first meeting of a newly formed group of amateur astronomers

James Webb I'm already lagging behind on Galaxy season. When the curfew is lifted here in Luxembourg, that's where I'm headed.

Mick Cassidy I can't wait to meet up with my astro buddies, set up the scopes and have a night of fun, laughter and observing. It's long overdue!

SCOPE DOCTOR

Our equipment specialist cures your optical ailments and technical maladies

With **Steve Richards**

Email your queries to
scopedoctor@skyatnightmagazine.com

I have a Meade ETX-125EC telescope that came with an SP26mm eyepiece, but I have since acquired three Meade series 5000 HD-60 eyepieces with 9, 12 and 18mm focal lengths. What types of target are each of the eyepieces best used for? CAROL BOLTON

The Meade ETX-125EC is a Maksutov-Cassegrain so it has a relatively long focal length of 1,900mm, making it a good choice for lunar and planetary observations where high magnifications are required. With it, your 26mm, 18mm, 12mm and 9mm eyepieces will deliver magnifications of 73x, 105x, 158x and 211x respectively.

Remember that higher magnification doesn't always improve the close-up detail in celestial objects, but with good seeing conditions this scope should give some great views of the planets with the 12mm eyepiece and under the best seeing conditions, the 9mm will excel. Under the best conditions the 9mm would also be suitable for splitting double stars.

▲ **The Meade ETX-125EC is good for lunar and planetary observing**

MEADE INSTRUMENTS UK

All of your eyepieces will produce interesting views of the Moon, from a field-filling view of the whole lunar disc in the 18mm eyepiece to good views of craters, mountains and rilles through the 9mm and 12mm ones. The 26mm and 18mm eyepieces would be well suited to deep-sky observations.

Steve's top tip

What is a Bahtinov Mask?

Accurate focus on deep-sky objects is key to successful imaging, but it's surprisingly difficult as many objects are too dim to focus on. However, focusing on a bright star is much easier and if the stars are in focus, deep-sky objects will be too. A Bahtinov Mask makes it easy to get stars in focus. It is a special grating that – when placed on the front of a telescope aimed at a bright star – produces a distinct diffraction pattern comprising an 'X' and a horizontal line. Capturing a series of exposures of the diffraction pattern and checking them allows you to adjust focus between images until the line perfectly bisects the 'X', which indicates the best focus position.

Steve Richards is a keen astro imager and an astronomy equipment expert

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Instagram

cxjones100 • 21 March

Last night I joined a sketching workshop with @shropastrosoc zoom meeting. It was run by astronomer Mary McIntyre FRAS @spiceyspiney who is a wonderful artist and full of enthusiasm. We were taught how to draw solar sunspots, Moon craters and DSOs. Amazing how much more you learn by drawing rather than photographing. Here's my attempt at Archimedes crater and M42.
Thanks Mary
#astronomy #astro #sketching #bbcskyatnightmagazine @

▸ when his name is Galileo Galilei, is this chap universally known by his Christian name?
Jim Hardy, Exmoor

Moon in miniature

I love the magazine, especially the 'Moonwatch' section. As an owner of a Sky-Watcher telescope and a keen observer of the Moon I decided to make a desktop Moonscape. I used a piece of 4-inch drainpipe and modelling clay to form the mould, and a variety of stones to make the features and texture. A suitable hard plaster was then poured into the mould. Once dry, it was painted and coated with a water-based varnish.
Chris Flatt, via email

Chris's desktop Moonscape

CORRECTION

• In the feature 'Where to Stargaze in England', page 70, April 2021 issue, the stargazing sites in Cranborne Chase AONB Dark Sky Reserve were chosen not by dark skies advisor Stephen Tonkin as stated, but by the AONB team before he arrived in his role.

SOCIETY IN FOCUS

I formed **Adur Astronomical Society** along with a friend of mine in 2011 and was assisted in doing so by the late Sir Patrick Moore, who gave me a lot of advice and even suggested our society name. Sir Patrick was our first Honorary President and invited members to his home on many occasions. Our launch was attended by over 90 people, including Sir Patrick, Nik Szymanek, Steve Richards and *The Sky at Night*'s Pete Lawrence, who gave a talk.

Membership increased over the following years and now stands at about 50 members, covering the Adur Valley area of West Sussex. Our members range from complete beginners to experienced astronomers, and we believe astronomy can and should be enjoyed by everyone.

In normal times we have two monthly meetings. One is held at Southwick Community Centre and is usually a lecture hosted by an expert speaker on a range of subjects. The other covers practical astronomy and is held at Westdene Green Community Barn, Brighton, adjacent to a green that is perfect for telescopes.

▲ **On the green: members of the Adur Astronomical Society before the pandemic**

We normally invite those thinking of buying a telescope, those who already have one and want to learn more, or those who just want a closer look at the night sky. The pandemic has put a hold on such meetings, but we are sharing information, advice and astro images via email, with a view to starting astronomy lectures over Zoom in the near future.
Robin Durant, president
▸ **www.adur-as.org.uk**

COVID-19
Online and socially distanced events taking place this month

We pick the best astronomy events and resources available online this month

WHAT'S ONLINE

PODCAST
Small Steps, Giant Leaps

The Ingenuity helicopter on Mars, the outer planets-bound Europa Clipper, the Swamp Works innovation centre, the Transiting Exoplanet Survey Satellite (TESS) mission and myriad other feats are the subject of the 50+ episodes of this podcast, meeting the NASA engineers and scientists that make these incredible projects a reality. **https://appel.nasa.gov/podcast**

PICK OF THE MONTH

▲ Excited about space: the hosts' enthusiasm makes *Space Explorers* a fun, engaging watch

CBeebies Stargazing: Space Explorers

A Solar System adventure mini-series for the very young

It's never too early to get kids interested in the wonders of the night sky. In this new five-part series, *Sky at Night* presenter Maggie Aderin-Pocock, children's TV doyen Chris Jarvis and Robert the Robot introduce pre-schoolers to the Solar System. Taking the Voyager missions as inspiration, they set a course for the Moon, Jupiter, Saturn, Neptune and beyond, using everyday objects and settings as proxies for the galactic marvels they encounter. As well as the 15-minute episodes, you'll find games, interactive quizzes, songs and more at **www.bbc.co.uk/cbeebies/shows/stargazing**

RADIO
Out of this World: The Colin Pillinger Story

Someone who'd have been elated about the slew of new Mars visitors was off-beat British planetary scientist and leader of the Beagle 2 Mars project, Colin Pillinger. Listen to his life story, narrated by Jon Culshaw. **www.bbc.co.uk/sounds/play/p064nm11**

ONLINE TALKS
Solar Observing on a Budget

This public lecture from solar expert Sheri Lynn-Karl of the British Astronomical Association (BAA) takes place on 20 May at 7:30pm, courtesy of the Astronomical Society of Glasgow. It can be accessed via Zoom at **bit.ly/solarobservingbudget**

Stellar Encounters

Take an expertly guided tour of the Solar System in the company of the Royal Observatory, Greenwich (ROG). This online planetarium show, presented by an ROG astronomer, takes place every Tuesday and Thursday at 3pm; 1pm and 2pm at weekends. It's £5 per device and free for members. **bit.ly/stellarencountersonline**

Bath Astronomers

Upcoming guests speakers at Bath Astronomers include Mary McIntyre, astro artist and astrophotographer, on 28 April, 7:30pm; the public can request Zoom details via hello@bathastronomers.org.uk. Then, on 26 May at 7:30pm, Pete Williamson's subject is 'From Herschel to Hawkwind'. This may be held live at Bath's Herschel Museum of Astronomy (tbc). Visitors (£5), juniors, students or Herschel Society members (£2), Bath Astronomers members (free). **bathastronomers.org.uk**

ONLINE GAME
The Gemini Card Game Online

Could you run a world-class observatory? The international Gemini Observatory has its own card game, which is available to play online for free. Recreating decisions made by observatories, two to four players work to complete observing programmes. **bit.ly/geminicardgame**

BBC X 4

The amateur astronomer's forum

FIELD OF VIEW

A wild night out under the stars

Steve Brown enjoys his encounters with wildlife during astronomy sessions

Steve Brown is a North Yorkshire-based astrophotographer and a highly commended finalist in the Astronomy Photography of the Year 2020 competition

As amateur astronomers, we spend a lot of time looking up at the night sky, but we can also enjoy the natural world all around us as we stargaze. I've had some fascinating encounters with nocturnal animals while out observing. I had rarely seen a hedgehog until a few years ago, when I started to regularly set my telescope up in my garden for a night's astronomy. With these creatures coming out of hibernation in the spring, it won't be long until my observing sessions are accompanied by the rustling noise of a hedgehog in the undergrowth, looking for a tasty slug to eat. I have even built a hedgehog house, to make my garden more welcoming to these animals.

However, it isn't just hedgehogs that you can see in your garden at night. Many moth species are active during the hours of darkness, such as the brimstone and the silver Y. If you have honeysuckle, jasmine or evening primrose in your garden, you may well see moths attracted to their evening scent. Moths and other flying insects are food for bats, which you could see swooping above your head at dusk. If you have a pond, keep an eye out for frogs as they take advantage of the cooler evenings to look for food.

When I'm observing at the edge of town, I often hear the call of a tawny owl. Sometimes they come into the neighbourhood and can be seen perched on rooftops. In the spring, you might also hear the screech of a barn owl. I had one memorable encounter in July 2019, as I was observing a partial lunar eclipse. A barn owl flew silently across the field I was in and I was able to watch it hunting for several minutes. With the partially eclipsed Moon in the background, it made for a very special evening.

I often do astronomy on the local moors and grouse can sound quite eerie in the middle of the night when I'm concentrating on the night sky, looking for meteors. The haunting scream of a fox can be quite unnerving too, especially if you are unfamiliar with the sound. When you are walking to your observing site, take a few moments to look at the ground as you may spot some of the smaller nocturnal creatures, such as the common lizard. When I'm driving to the local moors, I have to be aware of rabbits and sheep on the road at night.

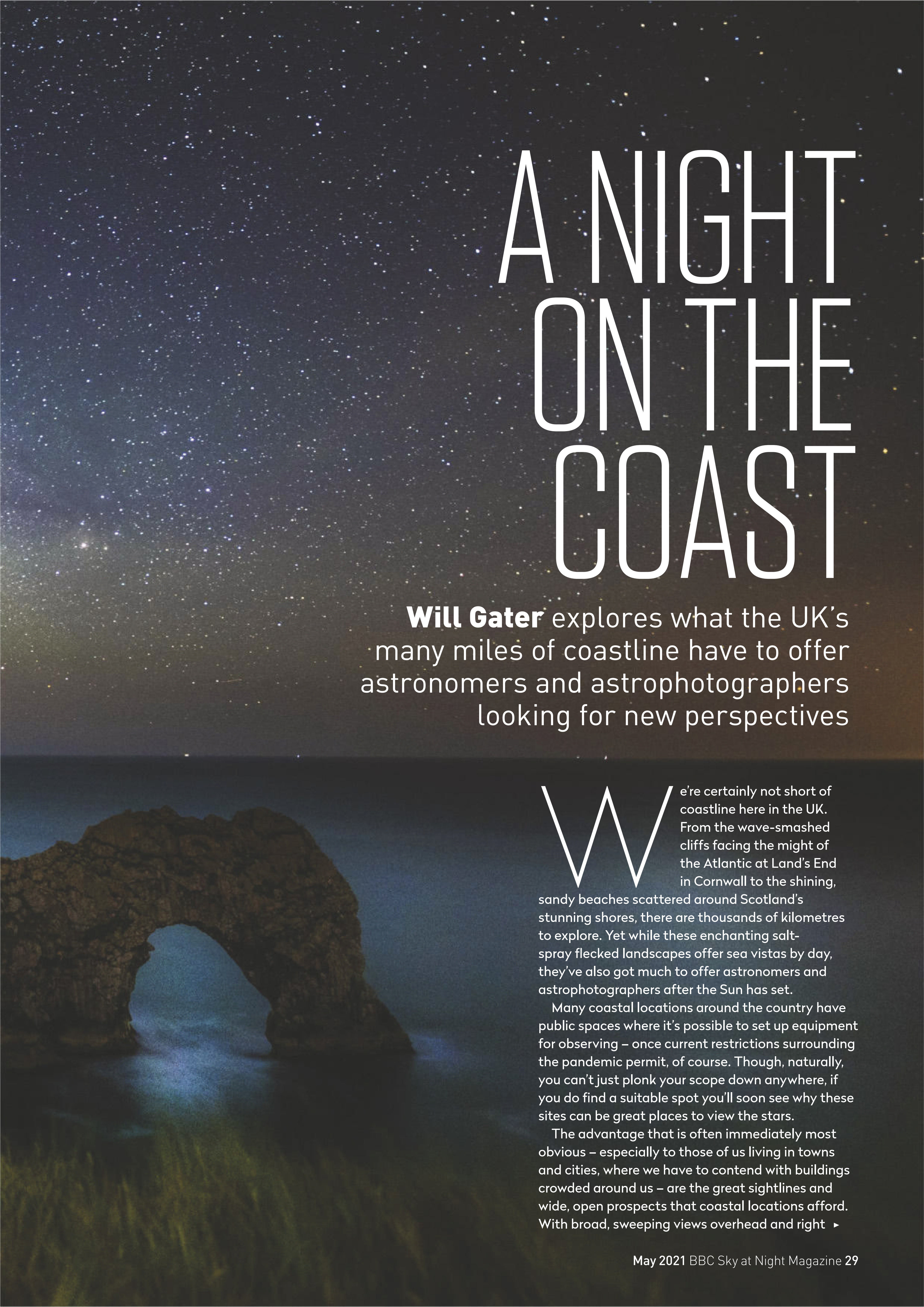
Sometimes though, something quite unexpected is seen. On the way to Kielder Observatory in Northumberland, I once had to slow right down as a badger was trotting along the road. It soon disappeared safely into the undergrowth but I was pleased to have seen one: my first, and so far only, encounter with a wild badger – albeit seeing its hind quarters bounding away from my headlights.

While out observing, you should also keep an eye out for that most nocturnal of creatures, the amateur astronomer. These are friendly and easily approached and if you're lucky, they may even share some of their astronomy and animal encounters with you!

HIFUMIYO/FOLIO

SCHROPTSCHOP/ISTOCK/GETTY IMAGES

Making the most of the coast: the wide open expanses of sky and sea can offer wonderful views of the night sky



A NIGHT ON THE COAST

Will Gater explores what the UK's many miles of coastline have to offer astronomers and astrophotographers looking for new perspectives

We're certainly not short of coastline here in the UK. From the wave-smashed cliffs facing the might of the Atlantic at Land's End in Cornwall to the shining, sandy beaches scattered around Scotland's stunning shores, there are thousands of kilometres to explore. Yet while these enchanting salt-spray flecked landscapes offer sea vistas by day, they've also got much to offer astronomers and astrophotographers after the Sun has set.

Many coastal locations around the country have public spaces where it's possible to set up equipment for observing – once current restrictions surrounding the pandemic permit, of course. Though, naturally, you can't just plonk your scope down anywhere, if you do find a suitable spot you'll soon see why these sites can be great places to view the stars.

The advantage that is often immediately most obvious – especially to those of us living in towns and cities, where we have to contend with buildings crowded around us – are the great sightlines and wide, open prospects that coastal locations afford. With broad, sweeping views overhead and right ►

Comet in sight: the sea affords a chance to see celestial objects skirting the horizon, like in this image of Comet NEOWISE captured above Anglesey in 2020

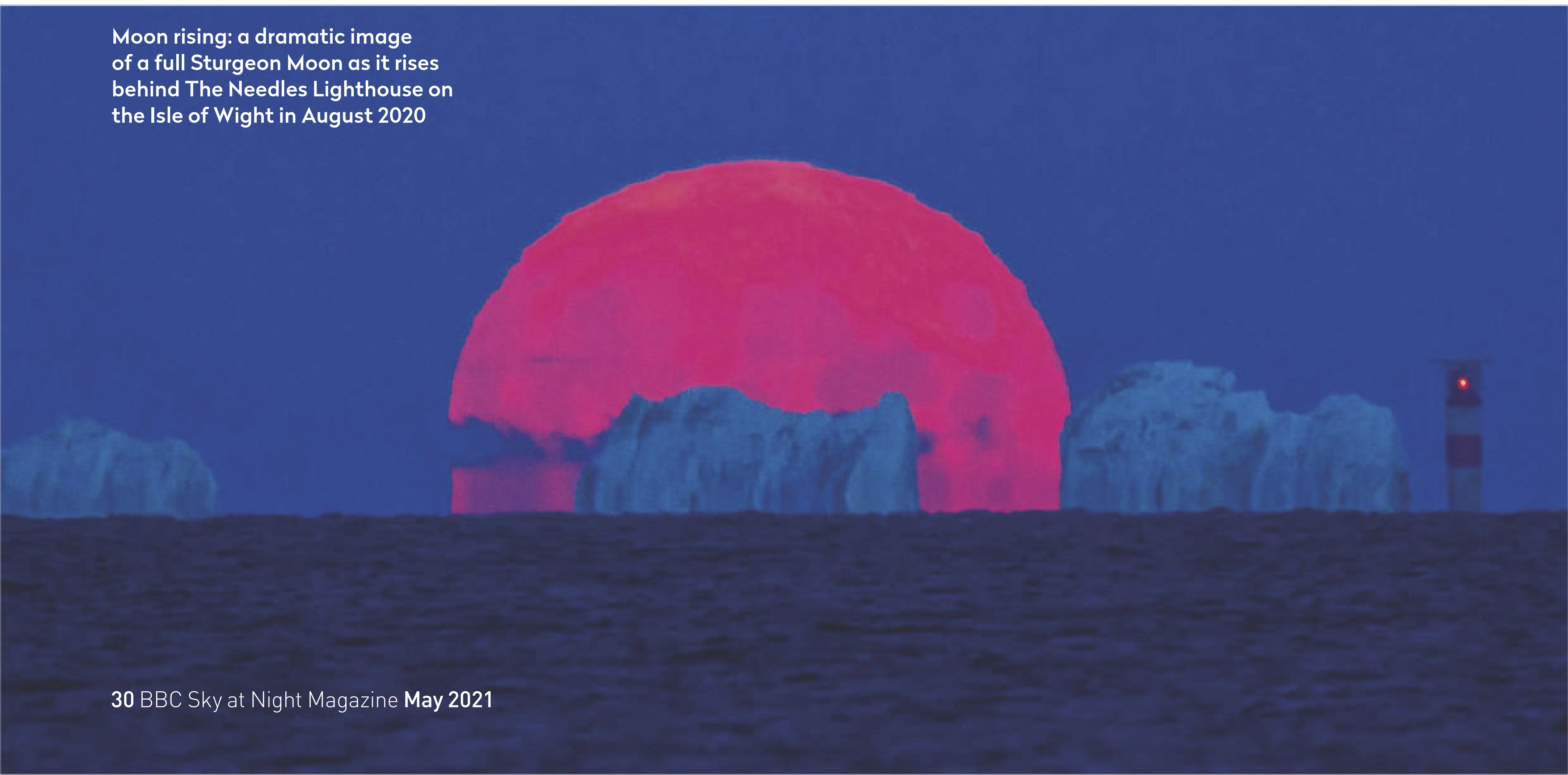
ALAN NOVELLI/ALAMY STOCK PHOTO, GRAHAM HUNT/ ALAMY STOCK PHOTO, SUSAN PILCHER X 2, WILL GATER

▸ down to the sea you're often able to see so much more sky than in a built-up urban location.

A coastal viewing site can be great for meteor-watching – especially during the stronger annual showers, like the Perseids in summer and the wintertime Geminids – as you've got a better chance of seeing meteors if you can see more sky. It can also be useful if you're a beginner trying to learn your way around the constellations, as it can be easier to relate different star patterns to one another when you can see more of them in a wider context. To add to this, anyone who's ever watched a moonrise over an eastward sea horizon will tell you just what a magical naked-eye sight that can be. Full Moon rises (see box, page 32) are particularly special, with the deep-orange lunar disc slowly appearing over the water and its 'glitter path' dancing as it climbs higher in the sky.

Revealing low objects

That brings us to another thing coastal viewing sites offer observers looking for a challenge: a view towards a flat sea horizon doesn't just provide a more open outlook, it also gives you pretty much your best chance of catching celestial objects that sit low in the UK sky – such as certain deep-sky targets and transitory sights like low-altitude comets. If you've got rooftops or trees and bushes around an inland site where you normally observe, chances are you've got a swathe of objects that you either can't view at all or struggle to see through the obstructions.



Moon rising: a dramatic image of a full Sturgeon Moon as it rises behind The Needles Lighthouse on the Isle of Wight in August 2020

Interview: Susan Pilcher

An astrophotographer based at Romney Marsh in Kent offers her thoughts about imaging at night along the UK coastline

What drew you to the coast as an astrophotography location?
I moved to Romney Marsh in Kent when I was 11, from Dover, and I suppose for me the coast is my go-to place. It's where I just feel really comfortable and happy.

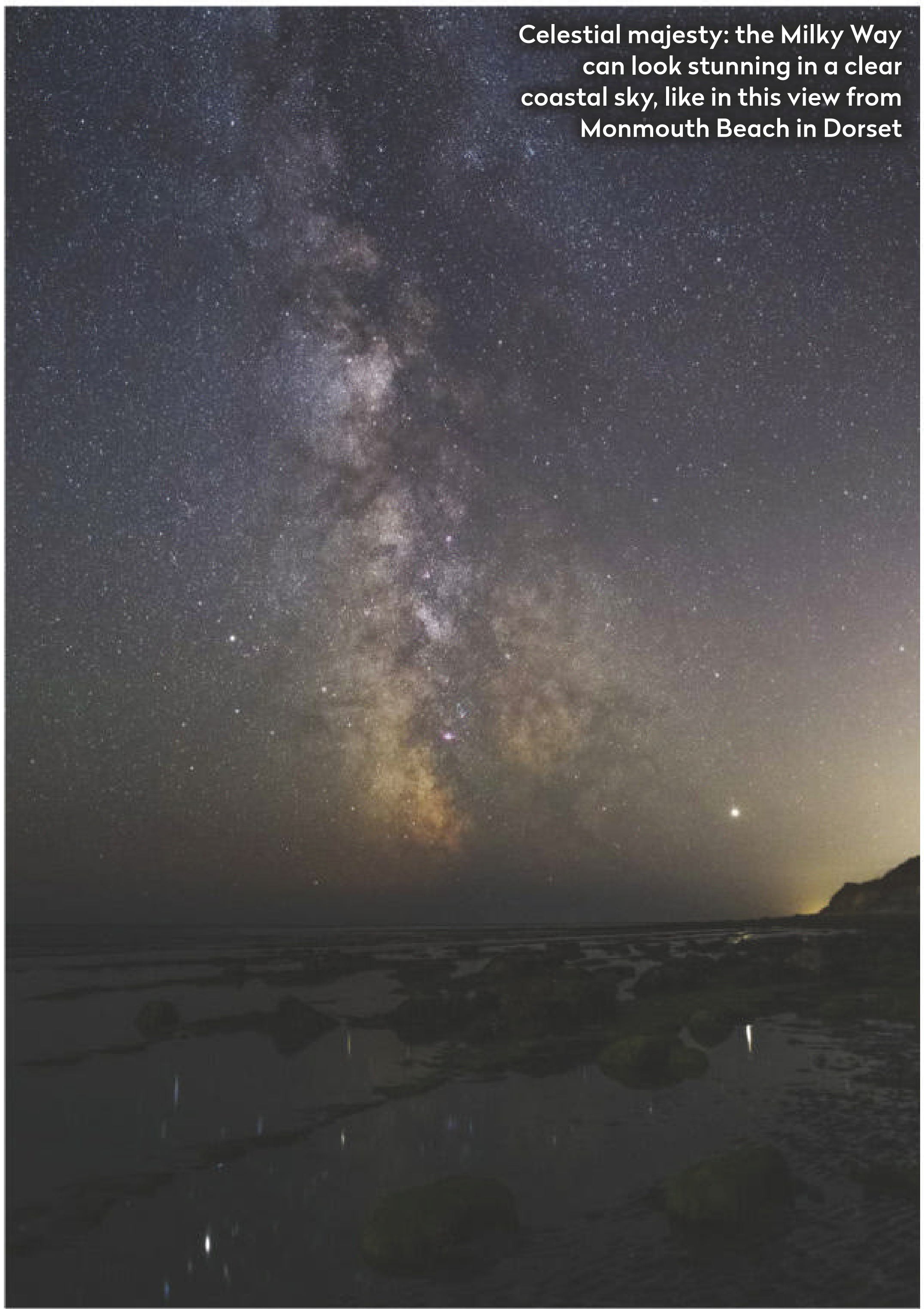
My favourite place to be photographing at night is Dungeness (also in Kent). It's such an amazing landscape, which is so open and barren, with big skies and lots of really flat land. You can see for miles.

What are your favourite celestial objects to shoot over that landscape?
I prefer the winter skies and I absolutely love seeing Orion rising up. [I try] to catch things with the different objects that there are down there – the fisherman's huts and boats and things like that.

What advice would you have for someone who is visiting the UK coast and who is trying to compose an astrophotograph?
Maybe do a bit of scouting out in the daytime, because when you get there at night it will be pitch black. You can't always see those shots, so maybe try to visualise it a little bit in the daytime.

What's been the most special thing you've caught in your astrophotos?
Certainly the bioluminescence – that was incredible. I've lived on Romney Marsh for 30-plus years and that was the first time I've ever seen it. I went up to the seafront around midnight and I thought, 'Gosh, that's really bizarre, there seems to be a funny bluey tinge on the water. Maybe it's a reflection from an LED streetlight.' But I didn't say anything to anybody. Within days it was all over Facebook; the amount of people that that photo brought out to see it was amazing.

▲ Night glow: Susan's stunning image of bioluminescence, which is caused by plankton



Celestial majesty: the Milky Way can look stunning in a clear coastal sky, like in this view from Monmouth Beach in Dorset

One of the richest regions of the sky that's often hard for UK-based observers to get a good look at – due to its inherently low altitude from UK latitudes – is the patch that sits towards the very centre of the Milky Way in the Northern Hemisphere summer months. This area, around the famous pattern of stars known as the 'Teapot' in the constellation of Sagittarius, the Archer, contains several truly superb observing targets for balmy summer nights; these include the beautiful Lagoon Nebula, M8 (see box, page 32) which is a great target for binoculars and a small telescope; as well as the globular cluster M22, which sits against the star fields of the summer Milky Way. As an example of how elusive these two objects can be with an obscured – in this case, southerly – horizon, around the time that darkness returns in early August in Scotland (at roughly 56°N latitude) both M8 and M22 sit well below 10° altitude; 10° on the sky, remember, is approximately equal to half the diameter of an outstretched hand at arm's length – not a great distance by any means. The situation for these celestial objects is only marginally better from the most southerly parts of the UK, which is why anything you can do to find a lower southern horizon – such as observing from a south-facing coast – will improve your chances of getting a clear view.

No land in sight

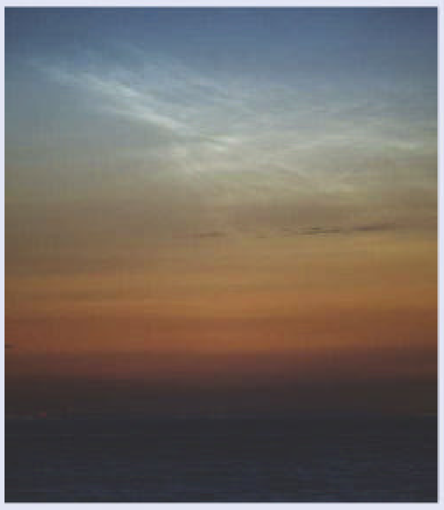
Those clear views can also be aided by the fact that when you're looking directly out to sea from the UK, there are generally no land masses for many tens, if not hundreds, of kilometres. This can mean there ▸

Seaside sights

Four of our favourite celestial sights to look out for when taking in the sea air at the coast

A full Moon rising

The rise of the full Moon over a sea horizon can be one of the most striking astronomical views you'll see from a coastal location – especially on those rare days of good sky transparency when there's little haze low down. As the disc of the Moon emerges into view, the atmosphere causes its coppery-red form to distort and shimmer, and this warping can be mesmerising in binoculars. As the twilight deepens, the moonlight on the water adds to the scene.

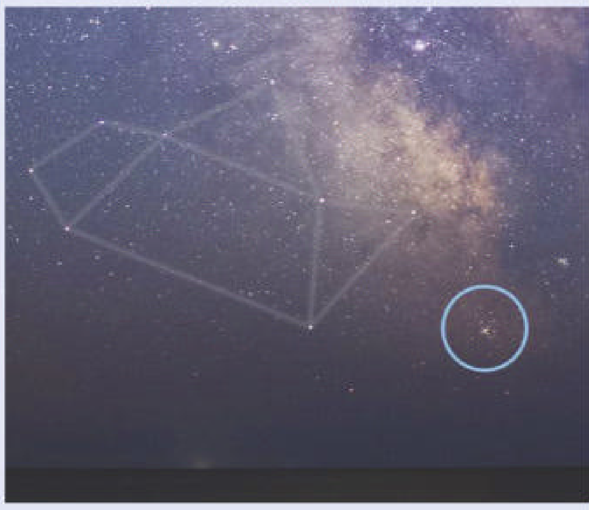


Noctilucent clouds

From late May, for a few summer months, it's noctilucent cloud (NLC) season in the mid-northern latitudes. These 'night-shining' clouds sit high in the mesosphere and can appear against a star-flecked twilight sky after sunset, or before dawn. From the UK's southernmost parts some displays hug the northern horizon, which means that north-facing coastal locations provide good observing spots, thanks to their typically open views down to a low altitude.

The Lagoon Nebula

If you were to write a list of the UK summer's top celestial sights, many would likely be ones sitting low in the sky. The Lagoon Nebula in Sagittarius, the Archer is a good example and is one to look out for – around 23:00 BST (22:30 UT) in late July and early August – if you're visiting a seaside spot with unobstructed views to the south. Under very dark skies it's actually visible to the naked eye and it's a lovely object when viewed with a wide-angle eyepiece on a small refractor.



Messier 7

Open star cluster M7, in the constellation of Scorpius, the Scorpion, is a challenging object to observe and image due to its low UK altitude in the summer night skies. Even from our most southerly coastlines it's a stretch and to get a reasonable view you'll need a night with good sky transparency near the horizon. It has a declination of nearly –35°, which means that from the south coast it sits only 4° above the horizon around 23:00 BST (22:00 UT) in late July.

▸ are far fewer light domes from towns and other settlements (near or far) on the horizon around you, making visual observing that much easier. What light pollution there is in a sea view is usually limited to the lights from distant ships or fishing vessels. Imagers may be able to pick up the light domes from very distant regions in long exposure nightscape-style images – for example, from the south Devon coast it's possible to detect the glow on the horizon from the Channel Islands and parts of northern France – but by and large you'll likely notice an improvement in light pollution levels compared to most inland UK sites.

Imaging possibilities

Speaking of imagers, all the benefits to visual observers mentioned above also apply to anyone trying to do astrophotography. For example, a coastal horizon, free of obstructions, enables you to shoot low-altitude displays of noctilucent clouds (see box, above). You'll also stand a better chance of capturing the glow of the Zodiacal Light over an inky-black expanse of sea than you might when looking out over inhabited regions in inland locations; in those spots, light pollution along the horizon can often swamp the lower-altitude part of this faint phenomenon. And all this is to say nothing of the innumerable aesthetic and compositional opportunities coastal astrophotography can bring.

Reflections – from bright planets, stars and the Moon – on rocks and wet sand can add a magical glittering quality to images. If you experiment with long exposures to blur the water and the motion of waves you can create luminescent textures in a scene that can grab the eye and pull the viewer into the composition.

▲ **Nocturnal effects: use long exposures to blur waves, and reflections to create eye-catching imagery like this view of Dorset's Mupe Bay**

WILL GATER X 4, TOMMY NAWRATIL/CCDGUIDE.COM, JOUEIN/ISTOCK/ GETTY IMAGES, DEFOREST/ALAMY STOCK PHOTO

Take care: you can capture stunning images from coastal locations, like this view of Jupiter and the Milky Way taken across the English Channel, but steer well clear of cliffs

Keep an eye on the weather: ensure your observing and safety isn't jeopardised by incoming fog, like in this scene at Stromness

Staying safe

Undoubtedly, though, the most important consideration when it comes to seaside stargazing must always be safety. The coast can be a dangerous location even in daylight, and at night there are numerous hazards that one needs to be mindful of too – slippery or uneven terrain, water and changing tides to name a few. Stay away from cliffs and other areas of dangerous ground and always consult the tide times, as well as any local safety information and signage. The usual advice for those venturing out to view or shoot the stars also applies – that is, tell someone exactly where it is you're going and when you expect to return, and dress for the conditions making sure to carry a fully charged phone and torch with you. A daytime recce of your intended viewing/photography spot can help you anticipate any issues – especially if it's an area you're not very familiar with.

The effects of inclement weather are often also keenly felt at exposed seaside spots, so you will – naturally – want to keep an eye on forecasts and the latest satellite imagery ahead of any trip. That's true not just from a safety point of view, but also because coastal spots can suffer from sea fog and haze, which can adversely affect observations. The Shipping Forecast, from the UK's Met Office, includes a general note about maritime visibility and there are also satellite images available online which can give hints of where fog may be forming. You'll also want to be wary of onshore breezes that can lift sea spray up into the air, as you don't want that getting anywhere near sensitive, or expensive, camera and telescope optics.

Whether you're an imager or an observer or a mixture of both, with the possibility that in the coming year we'll return to something resembling normal life, a trip to the coast might be just the thing that many of us need to reinvigorate our bond with the stars. Indeed, with plenty to be found shining above distant horizons to remind us why we took an interest in the night sky, the coast's greatest draw could well be the inspiration that flows from it as the waves lap and break in the salt-scented cool of the evening air.

Will Gater is an astronomy journalist and science presenter

'Great Globular': the Hercules Cluster, M13, is an impressive sight to observe with the naked eye, but it's stunning when viewed through a large scope

Like sugar on black velvet: OBSERVING GLOBULAR CLUSTERS

Spring is a great time to view these packed knots of stars. Globular fan **Ron Brecher** tells us how to track down the best examples now, and in later seasons


Super size: the giant elliptical galaxy M87 could harbour thousands of globular clusters

Where I live in southern Canada, the cold, cloud and snow can make winter observing a challenge, but eventually the temperatures moderate, the clouds part and the snow melts. That's when I get my 10- and 20-inch (250mm and 300mm) Dobsonian telescopes out to view my favourite eyepiece targets: globular clusters.

The best-in-class globular clusters are located in the Southern Hemisphere, where specimens such as Omega (ω) Centauri and 47 Tucanae outshine any globular visible from mid-northern latitudes. However, since most readers of this article, like me, are located north of latitude 40° North, I've focused on targets that are easily visible from my locale.

These spherical agglomerations of stars look good in any optics and, more than any other class of object, become more impressive with increasing aperture. 'Globulars', as they are sometimes called, are both beautiful and enigmatic; they can make you slow down to ponder the history and future of the cosmos. With so many targets to choose from, it's likely I've missed some of your favourite globular clusters, but I hope you'll enjoy this tour of some of my favourites!

I've always found that my eyepiece experience is enhanced when I understand a little about the nature of my observing targets. Globular clusters appear to be found in the haloes of most large galaxies, with numbers generally increasing with the size of the galaxy. For example, giant elliptical galaxy M87 may have more than 10,000 globulars, as compared to the Milky Way's 160 or so. Some sources say there may be a few more yet to discover in our home Galaxy. Most globulars contain hundreds of thousands of stars but some, like Omega Centauri, can host millions. We've known about globulars for a long time: the first observation was M22 (pictured, overleaf), by the German astronomer Abraham Ihle in 1665. ▸

BERNHARD HUBL/CCDGUIDE.COM, NASA/ESA AND THE HUBBLE HERITAGE TEAM (STSCI/AURA)


A simulated view of how globular cluster M22 would look through 7x50 binoculars

▸ The individual stars within globular clusters are rather faint as seen from Earth, so colour is elusive at the eyepiece. However, images of globular clusters often show more reddish stars than blue ones. This hints at their great age – often more than 10 billion years. Their stars are among the oldest in our Galaxy. It can be interesting to compare the eyepiece impression with what images capture.

Most of the hot blue stars have consumed their hydrogen fuel and dimmed, so the redder stars now dominate. Some of the blue stars in globulars belong to a group known as 'blue stragglers' – blue stars that have persisted longer than most. Their evolution is thought to be altered as a result of interstellar interactions in a globular's relatively high star-density environment.

The constellation of Ophiuchus contains 20 globular clusters that are visible in a 10-inch to 12-inch telescope under clear, dark skies

Views at the eyepiece

Although many of the most-viewed globulars appear visually similar to each other, there are interesting differences between them that are revealed through careful scrutiny. These will be discussed for individual targets below, but let's begin with some general things to look for when studying globular clusters at the eyepiece.

Most obvious, perhaps, is the variability in size and brightness, both of which depend upon distance, mass and any intervening dust. Distance rules, of course, and several of the closest and largest globulars are even visible to the naked eye. In the eyepiece in a dark sky, these brighter globulars give the impression of white sugar spilled onto a black velvet tablecloth.

Globular clusters also show different degrees of condensation in their cores, leading astronomers Harlow Shapley (read more about him in our 'Great Debate' feature on page 66) and Helen Sawyer Hogg to develop a system in the 1920s for classifying globulars from most to least concentrated, using Roman numerals 'I' through 'XII', respectively.

When I am looking at a globular cluster, I try to discern its shape (round or oval), whether I see any interesting patterns or tendrils of stars, and whether more outlying stars are visible if I increase magnification, thereby also increasing contrast. Any eyepiece impression is influenced by the surroundings within which an object is set. I enjoy hunting for galaxies near globular clusters – especially the spring globular clusters.

I also enjoy comparing and contrasting the views of globulars that are near each other in the sky. Some globular clusters seem to occur in groups, although this is mainly a line-of-sight phenomenon rather than them being real 'clusters of clusters'. This makes them easier to compare, because you don't need to move your telescope far between targets. For example, the constellation of Ophiuchus, the Serpent-bearer contains 20 globular clusters that are visible in a 10-to 12-inch (250mm to 300mm) telescope under clear, dark skies. In one marathon summer observing session, I saw 16 of them through a home-made 16-inch (400mm) reflector, before Ophiuchus set on that crisp, clear August night.

Spring and summer

I know spring has arrived when I can get a good look at M3 (pictured, below) in the late evening sky. Not

▾ **Good for starters: M3 is a good to begin with; it can be spotted in the spring, west of the main kite-shaped asterism in Boötes**

PETE LAWRENCE, RON BRECHER X 2, M10 & M12: LIM YUN CHONG/SINGAPORE

Two of a kind: globular clusters M12 and M10 appear close together, 3.25˚ apart, just south of the celestial equator

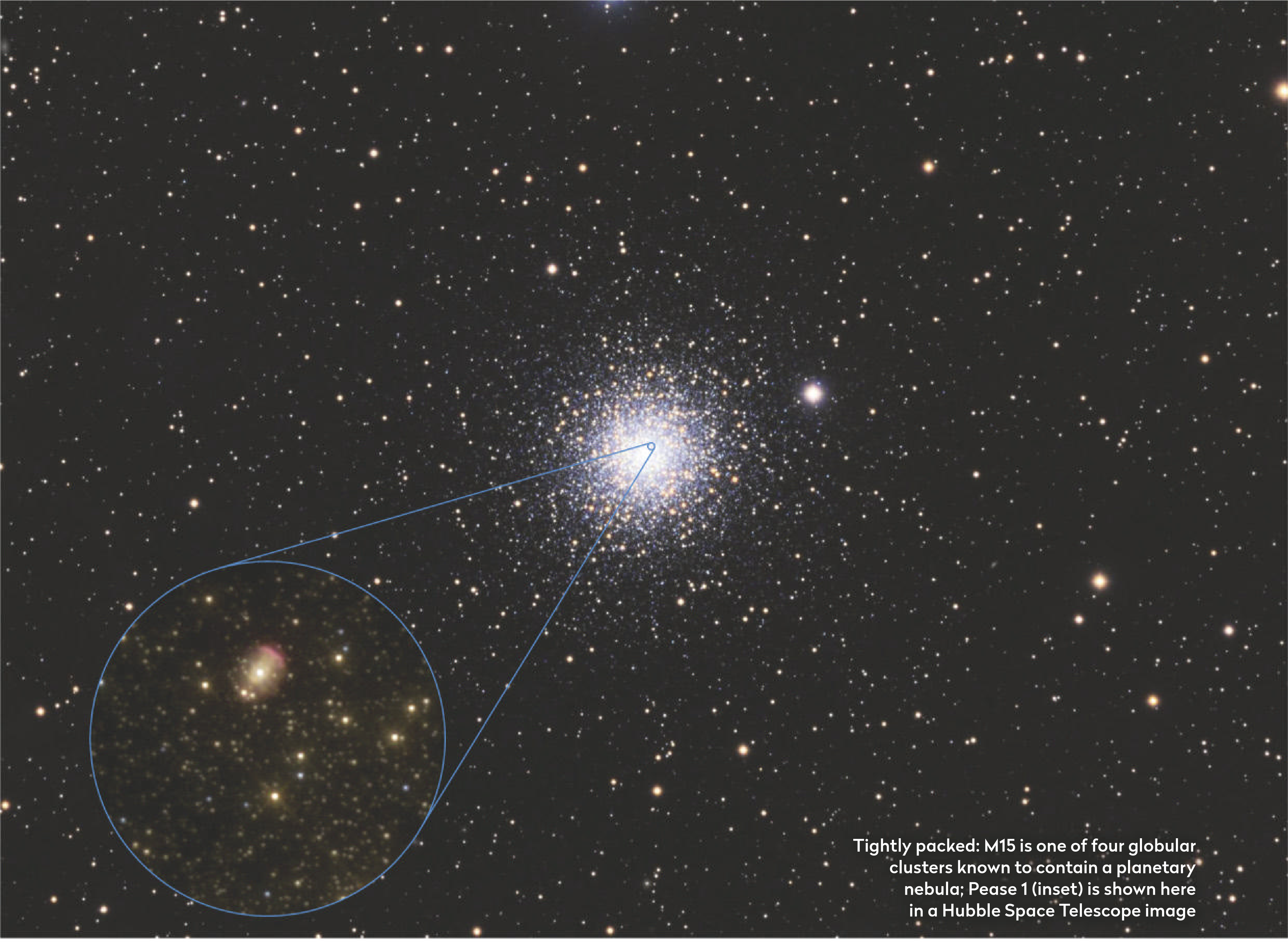
only is it one of the finest globulars in the sky, but its northern declination means it transits the meridian quite high up, where the sky is the most transparent. It's easy to find, located in the constellation of Canes Venatici, the Hunting Dogs, west of the main kite-shaped asterism in Boötes, the Herdsman. Point your finder to the third apex of a large equilateral triangle with Arcturus (Alpha (α) Boötis) and Rho (ρ) Boötis. M3 is barely below naked-eye visibility in binoculars. Its diameter is more than half the Moon's width, so it can fill the field of view in a medium-power eyepiece.

The globulars available for viewing come fast and furious by late spring, with M5 (pictured, right) being a must on your observing list. It is easy to star-hop to M5, since it's located at the western apex of a triangle formed with Alpha (α) Serpentis and Mu (μ) Serpentis. It's the brightest northern globular, at mag. +5.8, and one of the largest, so it is spectacular in the eyepiece of any scope. It is hard to discern where this cluster's edge is, as it seems to fade away into the background sky.

About 9˚ east of M5 and south of the celestial equator you'll find M12, with M10 (pictured, top) about 3.25˚ further east. M10 and M12 appear similar to each other in the eyepiece. For a very different eyepiece view, have a look at M107. It's about 9˚ due south of, and half the size of, M10. To my eye it appears to have a more well-defined edge than its larger cousin.

At almost the same right ascension as M12, but far to the north, you'll find one of the several candidates for best northern globular cluster – M13. Also known as the Hercules Cluster or the 'Great Globular', it is located just outside the longest edge of the Keystone asterism in the constellation of Hercules, the Hero about a third of the way from Eta (η) Herculis to Zeta (ζ) Herculis. I can just see it with my unaided eye in my Bortle 4 sky on the clearest, darkest nights. It is easy in 10x42 binoculars, pretty in my 6-inch (150mm) reflector, and spectacular in anything bigger. Southwest of the core there is a feature that looks clearly like a three-vaned propeller in images. It's harder to see visually, but larger apertures make it more apparent. If you need a faint fuzzy target after all that brightness, M13 shares a 1˚ field with two galaxies that are within visual range of amateur instruments. NGC 6207 isn't too tough to pick out less than a Moon width ▸


▲ **Shining out: M5, at mag. +5.8, is the brightest globular cluster in the northern sky**



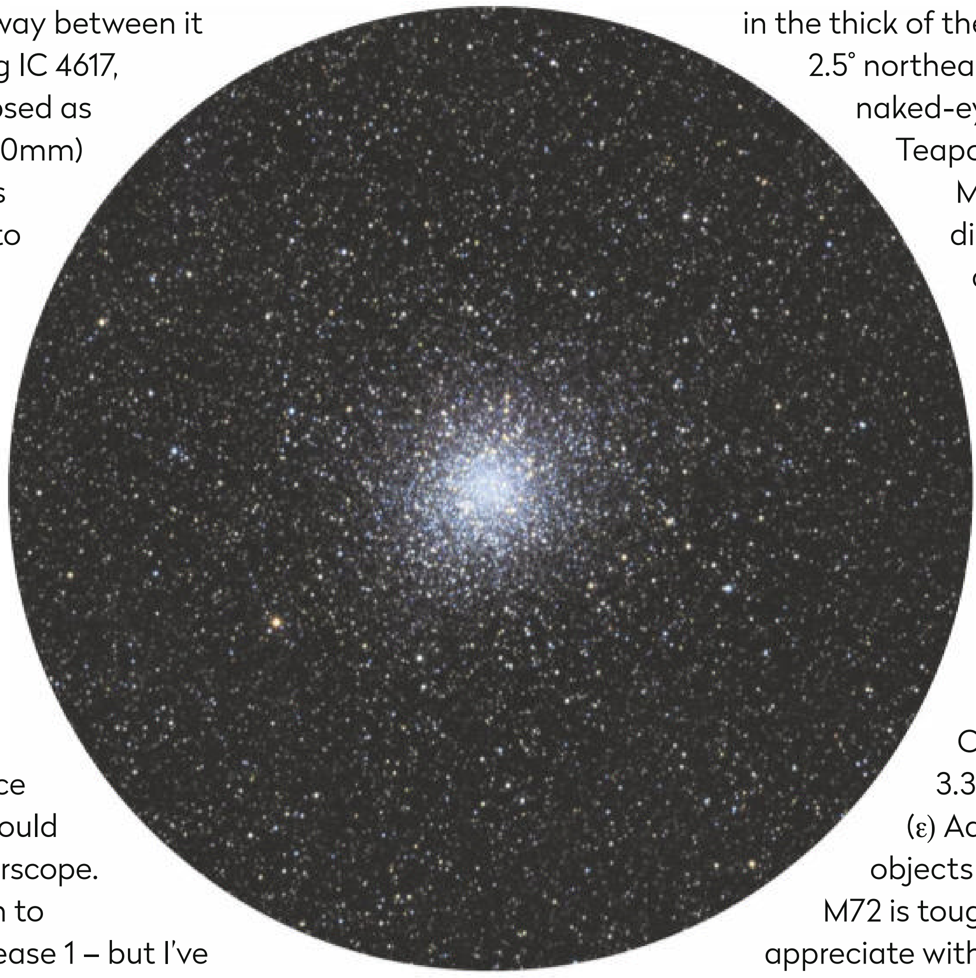
Tightly packed: M15 is one of four globular clusters known to contain a planetary nebula; Pease 1 (inset) is shown here in a Hubble Space Telescope image

▸ northeast of M13. About halfway between it and M13 is the more challenging IC 4617, which I have occasionally glimpsed as a fuzzy speck in my 20-inch (500mm) reflector. Since my skies are less than perfect, you may be able to spot it with smaller apertures.

Autumn onwards

In the second half of the year, M15 (pictured, above) is a bright (mag. +6.4) globular cluster that is easy to find from the nose of Pegasus, the Winged Horse. To locate it, connect the dots from Theta (θ) Pegasi to Epsilon (ε) Pegasi, also known as Enif. Continue about half the distance along the same line and you should spot M15 in binoculars or a finderscope. It is one of four globulars known to contain a planetary nebula – Pease 1 – but I've never been able to see its mag. +15.5 glow.

In early autumn you can be dazzled by another favourite globular cluster, M22 (pictured, right), which is located in Sagittarius, the Archer. If it were higher in the sky, it would rival every cluster mentioned so far. It is well-resolved in my 10-inch (250mm) reflector, and has an oval appearance in the eyepiece. It is set in the thick of the summer Milky Way, about 2.5˚ northeast of lamda (λ) Sagittarii, the naked-eye star that tops the lid of the Teapot asterism.



▲ **First discovery: M22 was discovered in 1665 and is one of the most visually impressive globular clusters from mid-northern latitudes**

RON BRECHER X 4

M71 is still impressive, but dimmer and smaller than M22, at around 7 arcminutes across. It appears in a field full of stars that enhance the view. Look just southeast of the line joining Gamma (γ) Sagittae and Delta (δ) Sagittae.

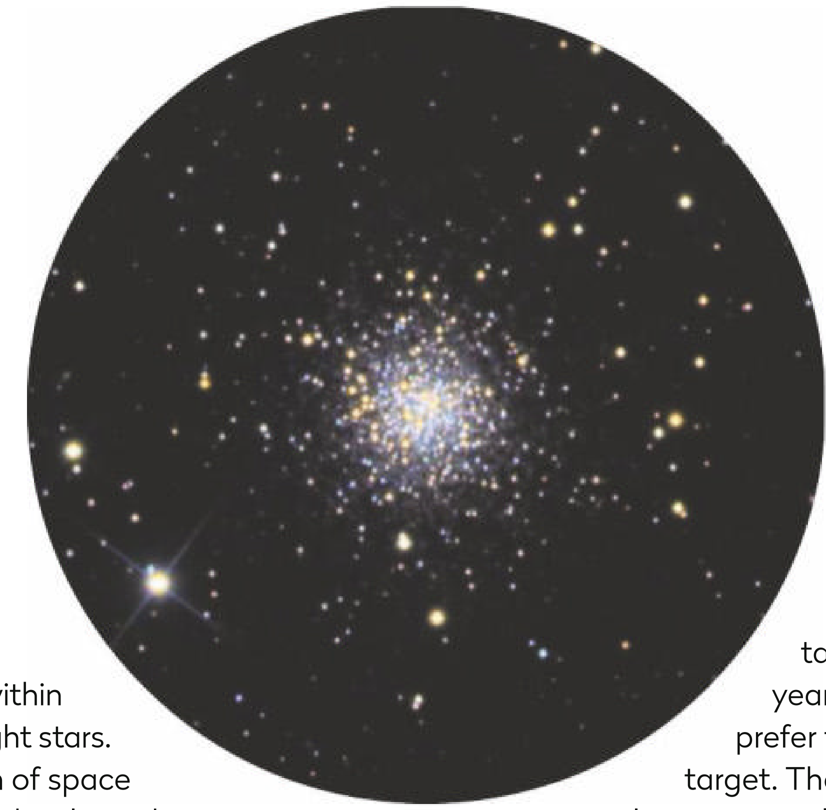
Moving to Aquarius, the Water-bearer, let your eyes dark adapt to get the best out of M72, the faintest globular cluster in the Messier Catalogue. It's located about 3.3˚ south-southwest of Epsilon (ε) Aquarii. Although all the Messier objects are visible in binoculars, M72 is tough to spot and even harder to appreciate without a larger instrument. My 10-inch (250mm) reflector at high power shows a fine gravelly texture, but individual stars are not distinct.

For a brighter target in Aquarius, visit M2; it makes an interesting comparison with M15, which is 13˚ to the north, since they're almost the same size and overall brightness. While M15 is, in fact, a little brighter, this impression is strongly enhanced for me

in small instruments by M15's much more concentrated core.

When I look at NGC 2419, the 'Intergalactic Wanderer' (pictured, below) I get a sense of loneliness and isolation. Lynx, the Cat, its home constellation, attracts little attention from observers, since it contains no splashy deep-sky objects. The field within which NGC 2419 lies contains few bright stars. Indeed, it lies at the edge of a region of space known as the 'Intergalactic Void' and the cluster has a small, distant appearance. It can be observed in small refractors, but looks much better at high powers in a larger instrument. Its apparent dimness belies its great intrinsic brightness, which is attenuated by its great distance. At around 300,000 lightyears, NGC 2419 lies further from Earth than the Milky Way's satellite galaxies, the Magellanic Clouds.

Globular clusters are fine observing targets regardless of whether you yearn for a faint-fuzzy hunt or would prefer to take in a bright, easy-to-find target. There are globulars accessible with almost every observing setup, from naked-eye to large-aperture scopes. Not only do larger scopes reveal more, but the more you look the more you see. You will want to go back to them over and over. And now with this article complete, I'm off to set up my homemade 10-inch reflector for an evening observing some – you guessed it – globular clusters!



▲ **Let your eyes dark adapt before seeking out the faint globular M72**

NGC 2419 lies at the edge of a region of space known as the 'Intergalactic Void' and has a small, distant appearance

Ron Brecher observes deep sky objects from his driveway in Ontario, Canada, while simultaneously imaging from his observatory. His images, article and more are available at **astrodoc.ca**

Lonely outpost: NGC 2419, nicknamed the 'Intergalactic Wanderer', gives an impression of isolation in the lesser-known constellation of Lynx

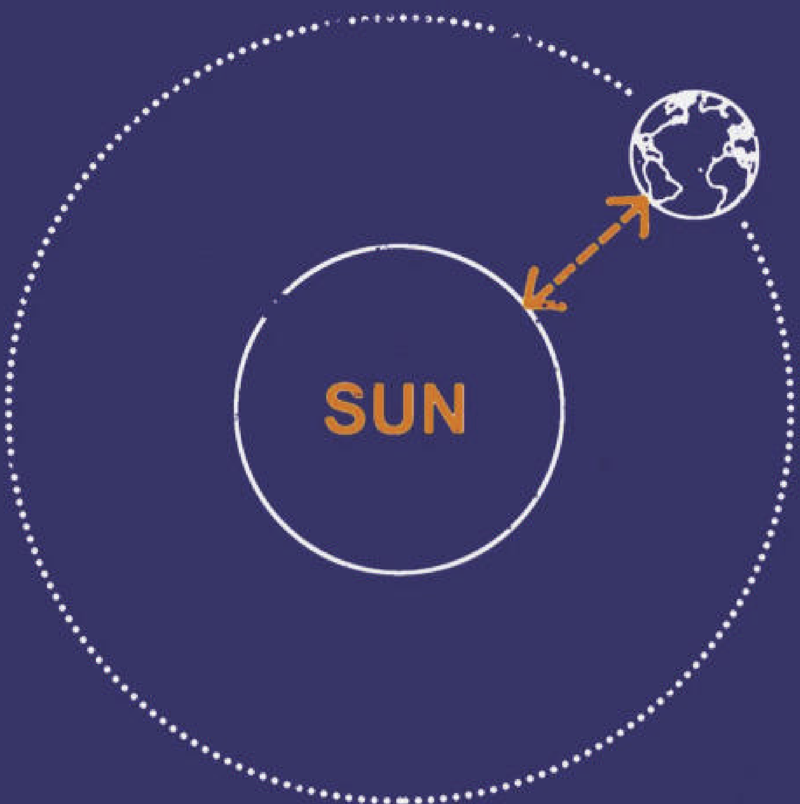
Seven steps to a HABITABLE PLANET

Govert Schilling is an astronomy journalist and broadcaster, and author of *Ripples in Spacetime*

In the search for exoplanets capable of supporting life, astronomers could be helped by looking for seven key features, reports **Govert Schilling**

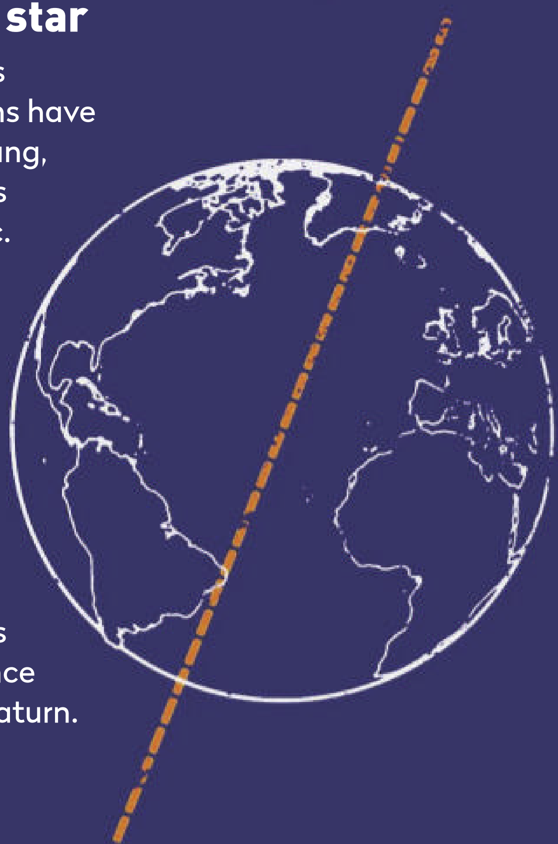
Which properties are essential for the origin and continued existence of life? And how did Earth acquire them? At a recent online astrobiology conference*, planetary scientist Alessandro Morbidelli (Nice Observatory, France) listed seven key features that could guide astronomers searching for inhabited extrasolar planets. Surprisingly, the slow, protracted growth of Earth, the interaction between Jupiter and Saturn, and the giant impact that formed our Moon may have been decisive factors in making a world that is hospitable to living beings. As Morbidelli says: "You need some luck."

*2021 Online Conference of the Dutch Origins Center, 27–28 January 2021



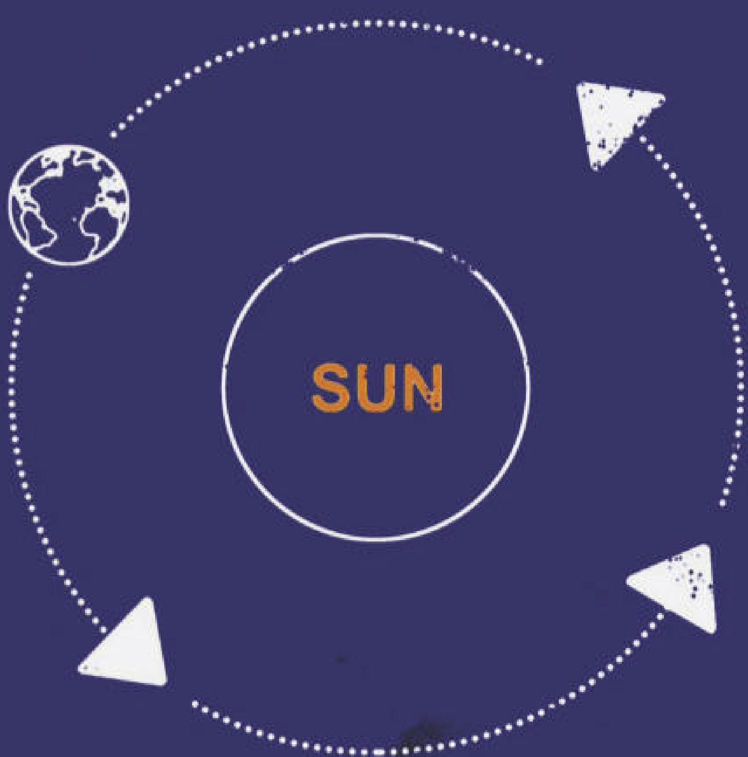
◁ 1. Right distance from their star

Obviously, Earth needs to orbit in the Sun's habitable zone. Many exoplanetary systems have planets much closer to their star, since young, full-grown planets tend to migrate inwards while embedded in the protoplanetary disc. Earth did not: it grew slowly, remaining too small to migrate during the disc's lifetime, probably because Jupiter blocked dust inflow from the outer Solar System. Then again, if Jupiter had migrated inwards, Earth would still have ended up close to (or even in) the Sun, or it might have been kicked out into interstellar space. According to Morbidelli, the fact Jupiter didn't migrate is likely to be due to the gravitational influence of a second giant planet in the system – Saturn.



2. More or less circular orbit ▷

Most extrasolar giant planets orbit their parent stars on elongated orbits. If that was the case for the giants in our Solar System, Earth's orbit would have become eccentric too. A stretched-out orbit means a varying climate, which could prevent the evolution of complex organisms, and even the origin of life. Apparently, we've been lucky that Jupiter remained on a rather circular path, despite its complex interactions with other planets.



△ 3. Stable rotational axis

Imagine that the tilt of Earth's axis varied by many tens of degrees over time spans of a million years or so. We know that's what happens to Mars, and these huge changes in axial tilt angle may have contributed to the loss of most of the Red Planet's atmosphere and water. Without Earth's more or less stable obliquity, life might have become extinct long ago, or it may never even have started. So what prevents our planet's axis from flipping in every possible direction? It's the stabilising influence of its large Moon. Next time you look at its pockmarked face, say thanks.

◁ 4. Some water, but not too much

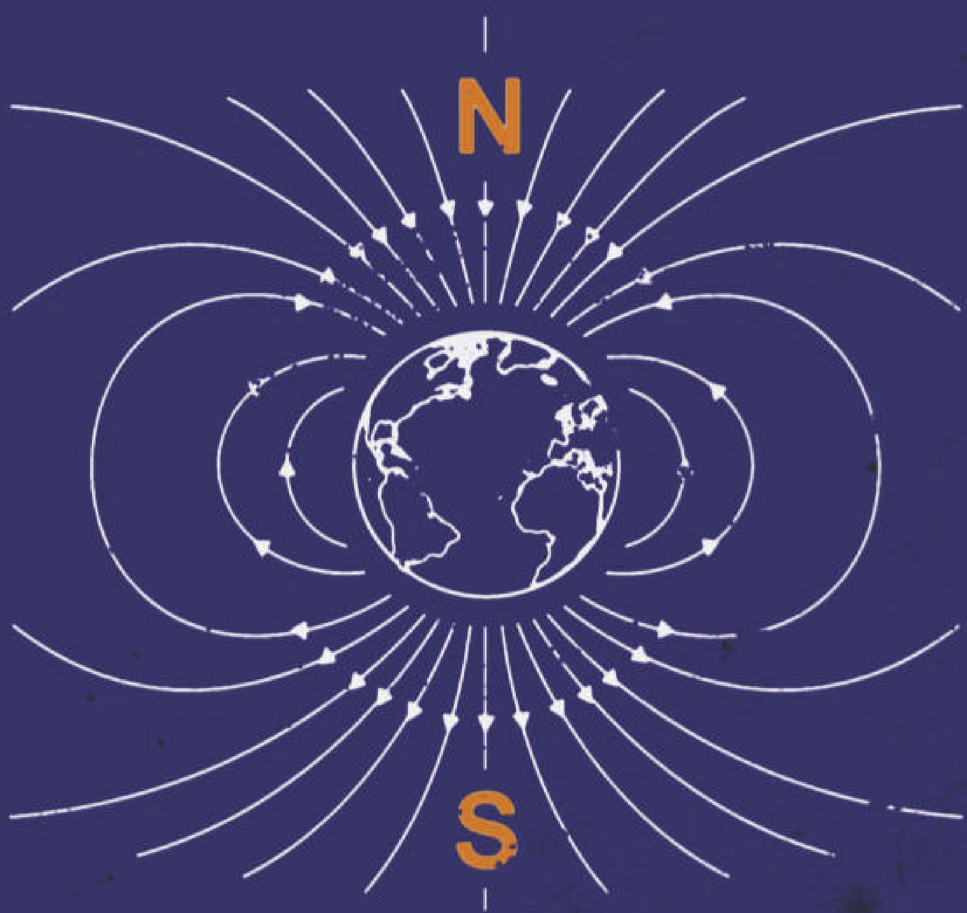
Life needs water – at least life as we know it. Most of Earth's water probably arrived after the planet's formation, by impacting asteroids and (to a lesser degree) comets. But fortunately, the amount of water brought in was relatively small. If Earth had become a water world, a deep layer of high-pressure, high-density 'tetragonal' ice would have formed at the bottom of the ocean, separating the liquid water from the mineral-laden crust. Without erosion-driven organics from the crust, says Morbidelli, the ocean would have remained sterile.

5. No hydrogen-rich atmosphere ▷

The solar nebula was more than 70 per cent hydrogen. If Earth had formed rapidly, it would have accreted a thick, dense atmosphere of hydrogen (and helium), ending up resembling the many 'mini-Neptunes' found among exoplanets. Life may have formed on such a world, but the oxygen produced by the first cyanobacteria would then combine with hydrogen to form water, and without an oxygen-rich atmosphere many complex life forms (humans included) would never evolve. Apparently, Earth formed slowly and relatively late, after much of the solar nebula had already dissipated. Lucky us.

◁ 6. Plate tectonics

Thanks to Earth's plate tectonics and associated volcanism, our planet has been able to regulate its climate, despite the fact that the Sun was much fainter long ago and has increased in brightness ever since. The well-known greenhouse gas CO^2 (carbon dioxide) is brought into the atmosphere by volcanoes, but washed away by rain storms, which are more frequent in warmer climates. Eventually, plate tectonics returns CO^2 back into Earth's lithosphere. Thus, the CO^2 cycle acts like a thermostat. So why does Earth have plate tectonics while Venus doesn't? It's most likely because of the giant impact from which the Moon was born, suggests Morbidelli.



7. Magnetic field ▷

Earth's global magnetic field shields surface life from the lethal effects of charged particles in the solar wind and in cosmic rays. The field is generated in the planet's molten outer core. Again, you may wonder why Venus (similar in size to Earth) does not have a magnetic field. The theory is that the giant Moon-forming impact messed up the nicely layered interior structure of Earth. As a result, both the core and the mantle became prone to convective motions, with a magnetic field and plate tectonics as a result, respectively. Without this cosmic catastrophe, our planet may well have remained a barren rock.

SON OF ALAN/FOLIO

BBC Sky at Night MAGAZINE

16-PAGE CENTRE PULLOUT

The Sky Guide

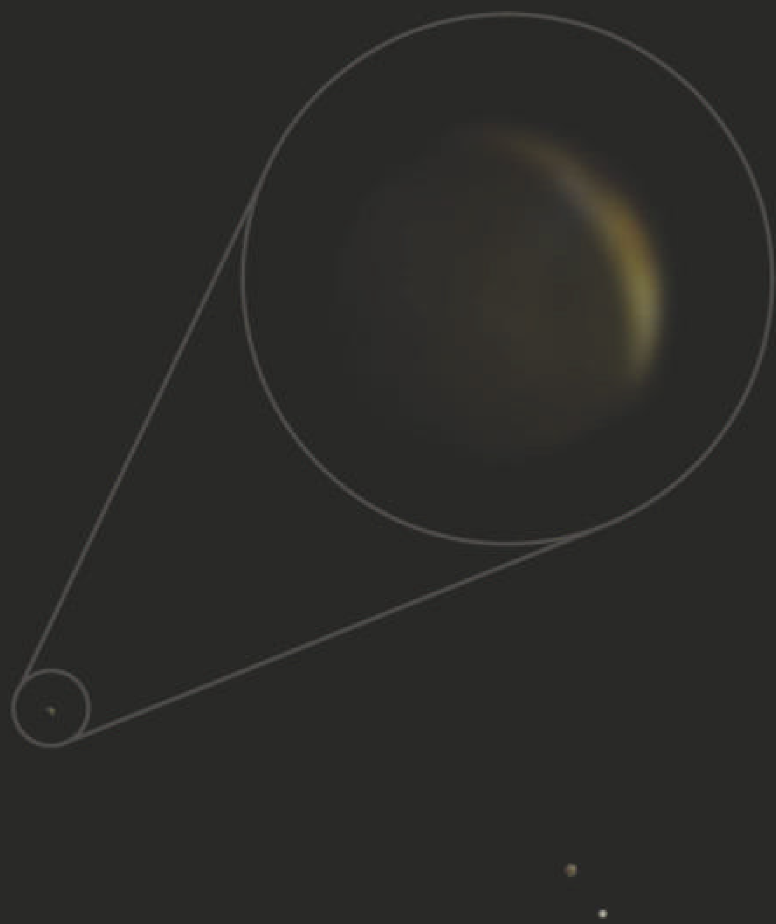
MAY 2021

CATCH AN ECLIPSE OF JUPITER'S MOONS

Observe Ganymede's shadow as it partially eclipses Io

EVENING ENCOUNTER

View Venus near a thin crescent Moon



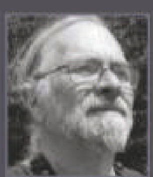
TRAIL FINDER

How to spot the peak of the Eta Aquariid meteor shower

PETE LAWRENCE

About the writers

Astronomy expert **Pete Lawrence** is a skilled astro imager and a presenter on *The Sky at Night* monthly on BBC Four

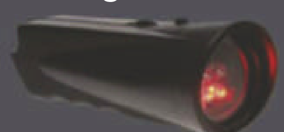


Steve Tonkin is a binocular observer. Find his tour of the best sights for both eyes on page 54

Also on view this month...

✦ Noctilucent cloud season begins
✦ The lunar 'X' and 'V' clair-obscur effects
✦ The year's brightest and largest full Moon

Red light friendly



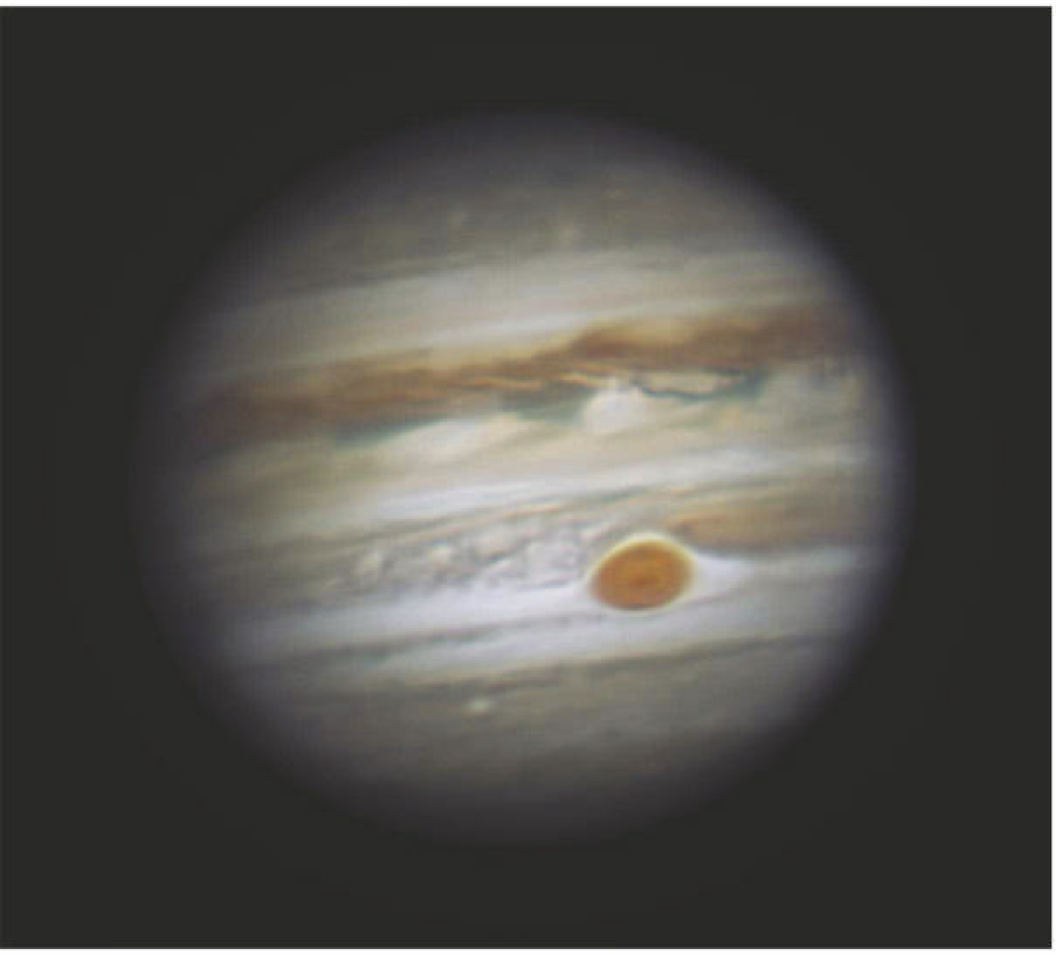
To preserve your night vision, this 'Sky Guide' can be read using a red light under dark skies

Get the Sky Guide weekly

For weekly updates on what to look out for in the night sky and more, sign up to our newsletter at **www.skyatnightmagazine.com**

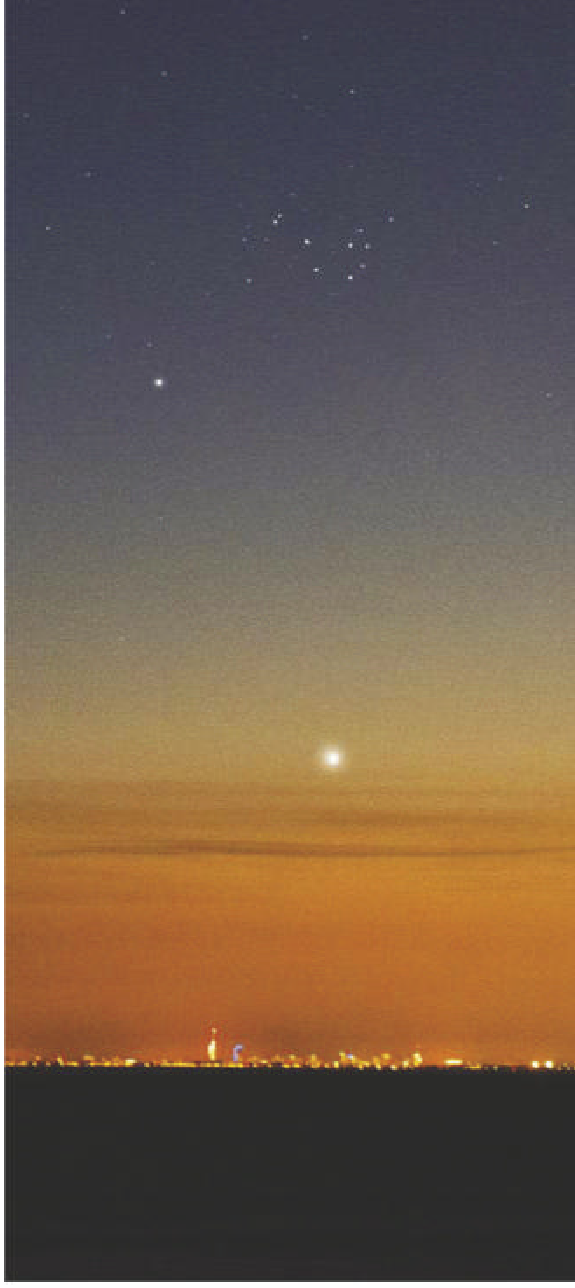
MAY HIGHLIGHTS

Your guide to the night sky this month



Sunday 2
Jupiter reaches an equinox. Sideways on to the Sun, this is the optimum time for its four largest Galilean moons to appear to interact with one another. Occultations, transits and eclipses between moons are possible in the months around the gas giant's equinox.

Monday 10
With the Moon out of the way, this is a great time to take our 'Deep-Sky Tour' on page 56 and explore the border of Cygnus and Cepheus.



Thursday 13
This evening's 3%-lit waxing crescent Moon lies 2.7° from mag. +0.2 Mercury. The Moon, Mercury and mag. –3.8 Venus make a Sun-pointing isosceles triangle above the west-northwest horizon, visible approximately 40 minutes after sunset.

Friday 14
Ganymede's shadow partially eclipses Io between 04:43–04:53 BST (03:43–03:53 UT).

Saturday 15
This evening's 14%-lit waxing crescent Moon occults mag. +3.0 Mebsuta (Epsilon (ε) Geminorum) from around 23:35 to 00:04 BST (22:35 to 23:04 UT). Mars is located 3.3° west of the Moon at the end of the occultation.

Monday 17
Mercury reaches greatest eastern elongation, separated from the Sun by 22° in the evening sky. Catch it and its inner Solar System neighbour Venus, from about 40 minutes after sunset low above the northwest horizon.

Wednesday 19
The bright star 4° below the Moon this evening is mag. +1.3 Regulus (Alpha (α) Leonis).

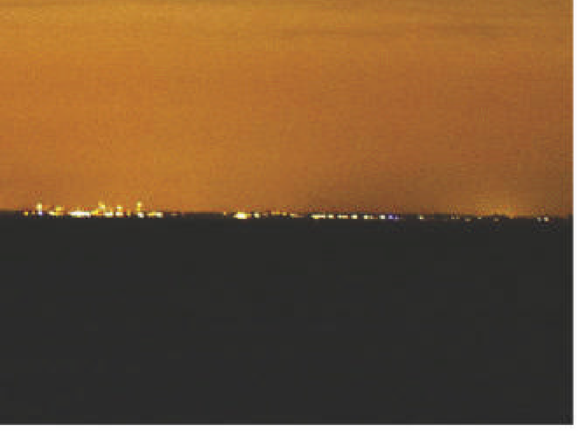
Sunday 23
The bright star below and to the right of the Moon as seen from the UK this evening is mag. +1.0 Spica (Alpha (α) Virginis).

Wednesday 26
Today's full Moon occurs approximately 9 hours after perigee, making this the brightest and largest 'supermoon' of 2021.

Friday 28
Visible approximately one hour after sunset, mag. –3.8 Venus is currently half a degree from mag. +2.3 Mercury, low above the northwest horizon.

Saturday 29
Ganymede's shadow eclipses the majority of Io's disc this morning from 03:27–04:17 BST (02:27–03:17 UT).

PETE LAWRENCE X 7



Tuesday 4

A tricky catch low above the northwest horizon, mag. –0.8 Mercury will appear 2.3˚ south of the Pleiades open cluster this evening. Look low above the west-northwest horizon 30 minutes after sunset to locate mag. –3.8 Venus. Mercury appears 6.3˚ above and slightly left of Venus as seen from the UK.

Thursday 6

The Eta Aquariid meteor shower peaks at 04:00 BST (03:00 UT). The observing window is short from the UK between 02:30 BST (01:30 UT) and the start of morning twilight.

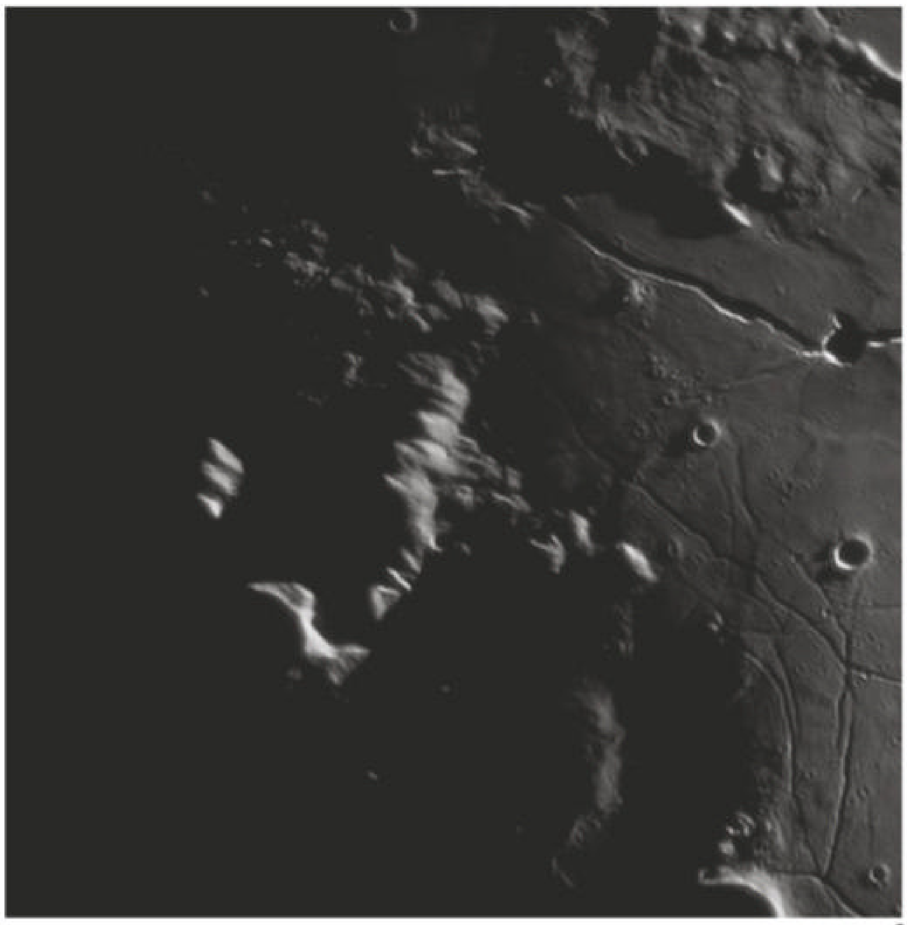
Io's shadow eclipses Europa from 04:26-04:32 BST (03:26-03:32 UT).

Wednesday 12

There's a thin Moon viewing opportunity this evening. Locate the bright mag. –3.8 planet Venus low above the west-northwest horizon about 30 minutes after sunset. A less than 1%-lit waxing crescent Moon sits 2˚ below the planet as seen from the UK.

Tuesday 18

The clair-obscur effects known as the lunar 'X' and 'V' occur tonight. The giant floating letters start to form on the Moon's terminator in the run up to midnight, fully formed around 00:44 BST on 19 May (23:44 UT on 18 May).



Monday 24

The last week of May signals the start of noctilucent cloud season. These are seen until early August, 90–120 minutes after sunset low above the northwest horizon or a similar time before sunrise low above the northeast horizon.

Monday 31

Mag. +0.7 Saturn sits 5˚ above this morning's 72%-lit waning gibbous Moon as seen from the UK.

Family stargazing

Venus now appears in the evening sky after sunset. It's a bright planet, easy to spot as long as you have a relatively flat west-northwest to northwest horizon. Leave about 20 minutes after sunset before looking for Venus low down. It may be a challenge at first, but it's like spotting the first star appearing as darkness falls; once you've seen it, it's difficult to miss. If you locate Venus try for Mercury, which appears above and to the left of Venus for all but the very end of the month. On 28 May, Mercury and Venus appear right next to one another, although Venus outshines its neighbour. **www.bbc.co.uk/cbeebies/shows/stargazing**

NEED TO KNOW

The terms and symbols used in The Sky Guide

Universal time (UT) and British Summer Time (BST)
Universal Time (UT) is the standard time used by astronomers around the world. British Summer Time (BST) is one hour ahead of UT

RA (Right ascension) and dec. (declination)
These coordinates are the night sky's equivalent of longitude and latitude, describing where an object is on the celestial 'globe'

Family friendly
Objects marked with this icon are perfect for showing to children

Naked eye
Allow 20 minutes for your eyes to become dark-adapted

Photo opp
Use a CCD, planetary camera or standard DSLR

Binoculars
10x50 recommended

Small/medium scope
Reflector/SCT under 6 inches, refractor under 4 inches

Large scope
Reflector/SCT over 6 inches, refractor over 4 inches

GETTING STARTED IN ASTRONOMY

If you're new to astronomy, you'll find two essential reads on our website. Visit **http://bit.ly/10_easylessons** for our 10-step guide to getting started and **http://bit.ly/buy_scope** for advice on choosing a scope

THE BIG THREE The three top sights to observe or image this month

DON'T MISS

JOVIAN EQUINOX

BEST TIME TO SEE:
6, 14 and 29 May at specified times

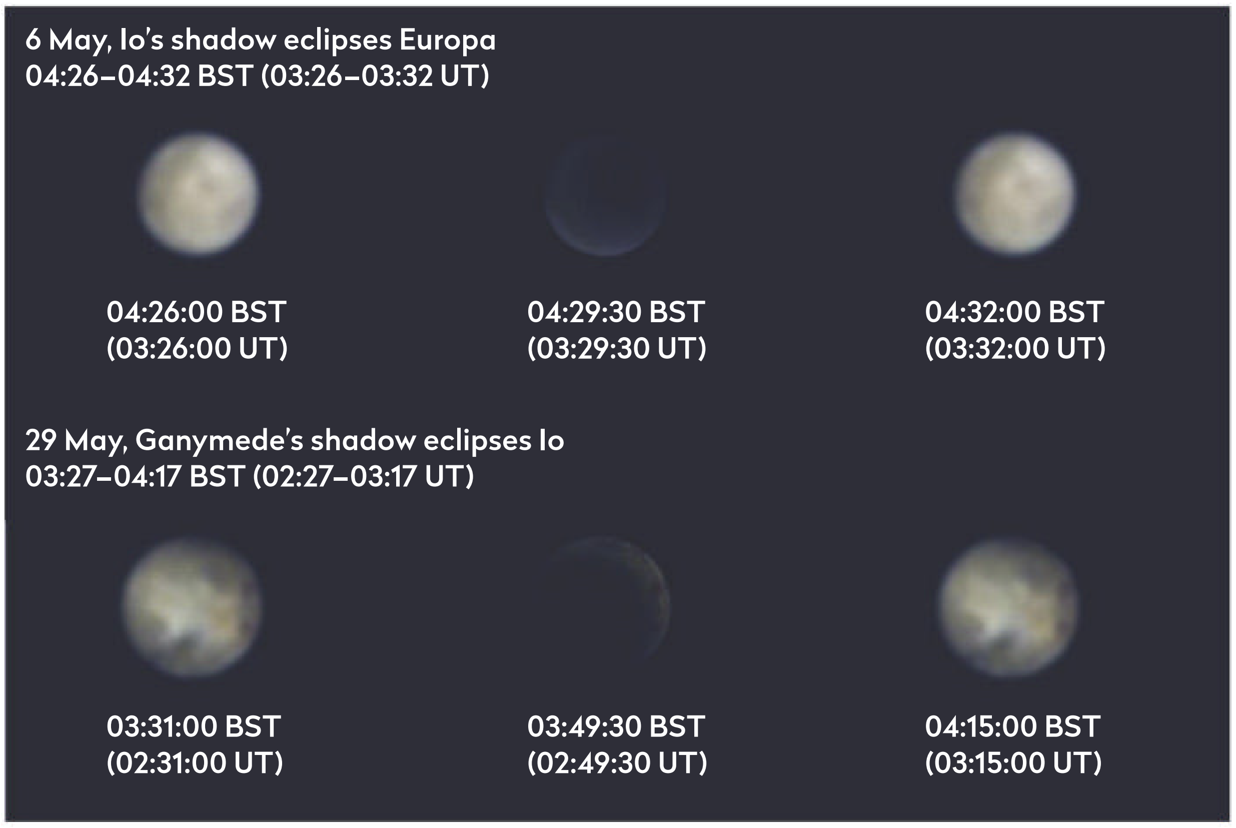
Jupiter reaches equinox on 2 May, a position where the geometric centre of the Sun's disc appears to cross the equatorial plane of the planet. Compared to Earth, Jupiter's axial tilt is quite small; 3.3° compared to our planet's 23.4°. For this reason, seasonal variations on Jupiter are relatively minor. Of more significance from our perspective, the four Galilean moons Io, Europa, Ganymede and Callisto, have orbits which are only slightly inclined to Jupiter's equatorial plane.

At those times away from an equinox, if the orbits of these moons were directly visible, from the Sun they would appear like narrow ellipses. Near to a solstice – a position where one of the planet's poles points maximally towards the Sun – the orbit ellipses would appear to have maximum width. Near a Jovian solstice, the edges of the orbital ellipses would all intersect Jupiter's disc with the exception of Callisto's. However, near to a Jovian equinox, all of the ellipses would appear so narrow from the perspective of the Sun that they would be lines representing the moon orbits seen edge on.

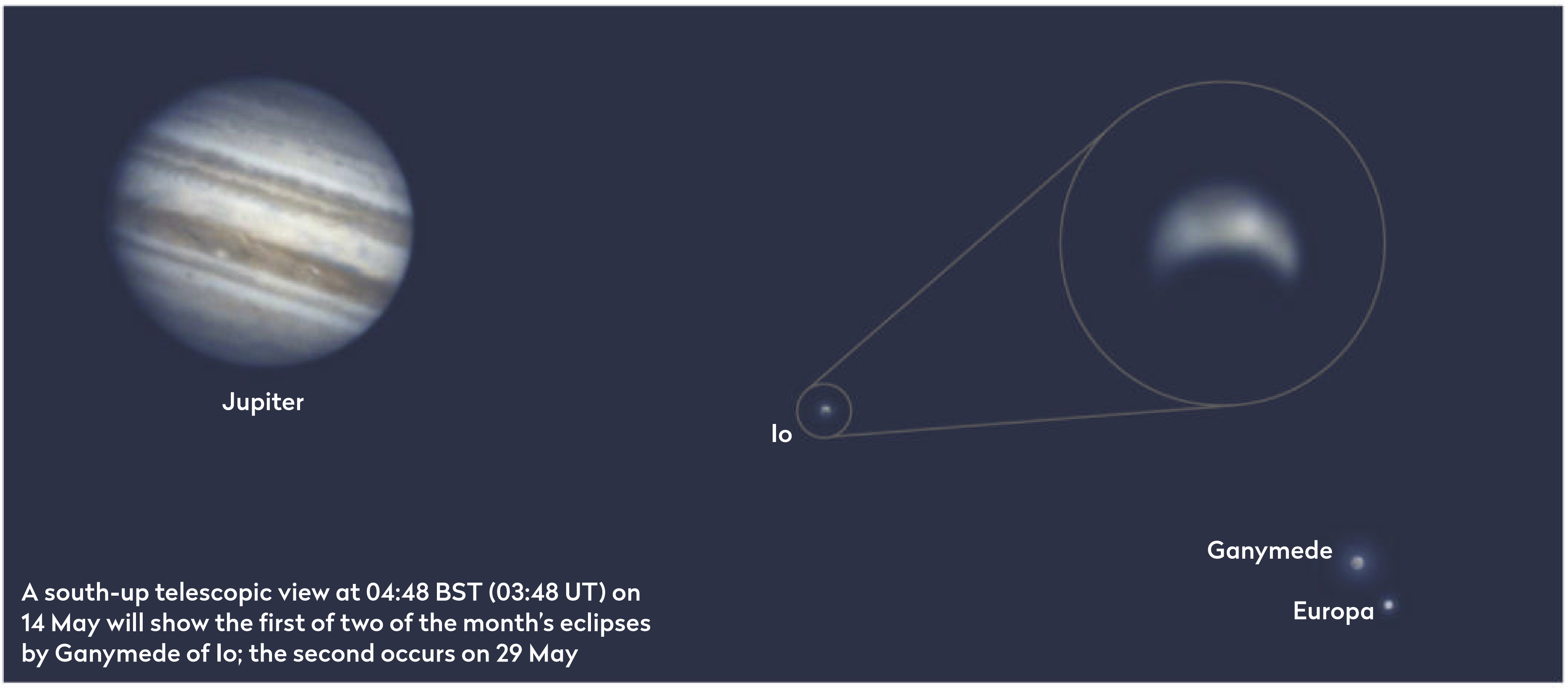
From Earth this creates interesting opportunities, as our view of the orbital ellipses isn't that different to the Sun's. Near a Jovian equinox we see the Galilean moons shuffling back and forth either side of the planet in an almost straight line. The alignment relative to the Sun allows the shadows of each moon to interact with other moons. Around a Jovian eclipse it's possible to witness moon-moon transits, occultations and eclipses – which are collectively known as mutual events.

On 6 May, Io's shadow eclipses Europa from 04:26-04:32 BST (03:26-03:32 UT). Then on the 14th, it's Ganymede's shadow which eclipses Io between 04:43-04:53 BST (03:43-03:53 UT). Then, from 03:27-04:17 BST (02:27-03:17 UT) on 29 May, Ganymede's shadow takes another swipe at Io and covers the majority of Io's disc.

The visibility of these events varies depending on where Jupiter is in the sky. The event on 6 May occurs under brightening sky conditions with Jupiter just 8° above the southeast horizon. The 14 May event fares a little better in terms of altitude, Jupiter appearing 13° above the southeast horizon by the time it starts. The event on 29 May occurs with Jupiter 11° up under lightening dawn twilight skies.



▲ **Moon shadows: observe Io eclipsing Europa (6 May) and Ganymede eclipsing Io (29 May)**



A south-up telescopic view at 04:48 BST (03:48 UT) on 14 May will show the first of two of the month's eclipses by Ganymede of Io; the second occurs on 29 May

ALL PICTURES: PETE LAWRENCE

Eta Aquariid meteor shower

BEST TIME TO SEE: Morning of 6 May

The Eta Aquariid meteor shower reaches its peak on the morning of 6 May. On this date, the shower's zenithal hourly rate (ZHR) should reach 55 meteors per hour, although with a low altitude radiant, the visual rate you actually see will be significantly lower.

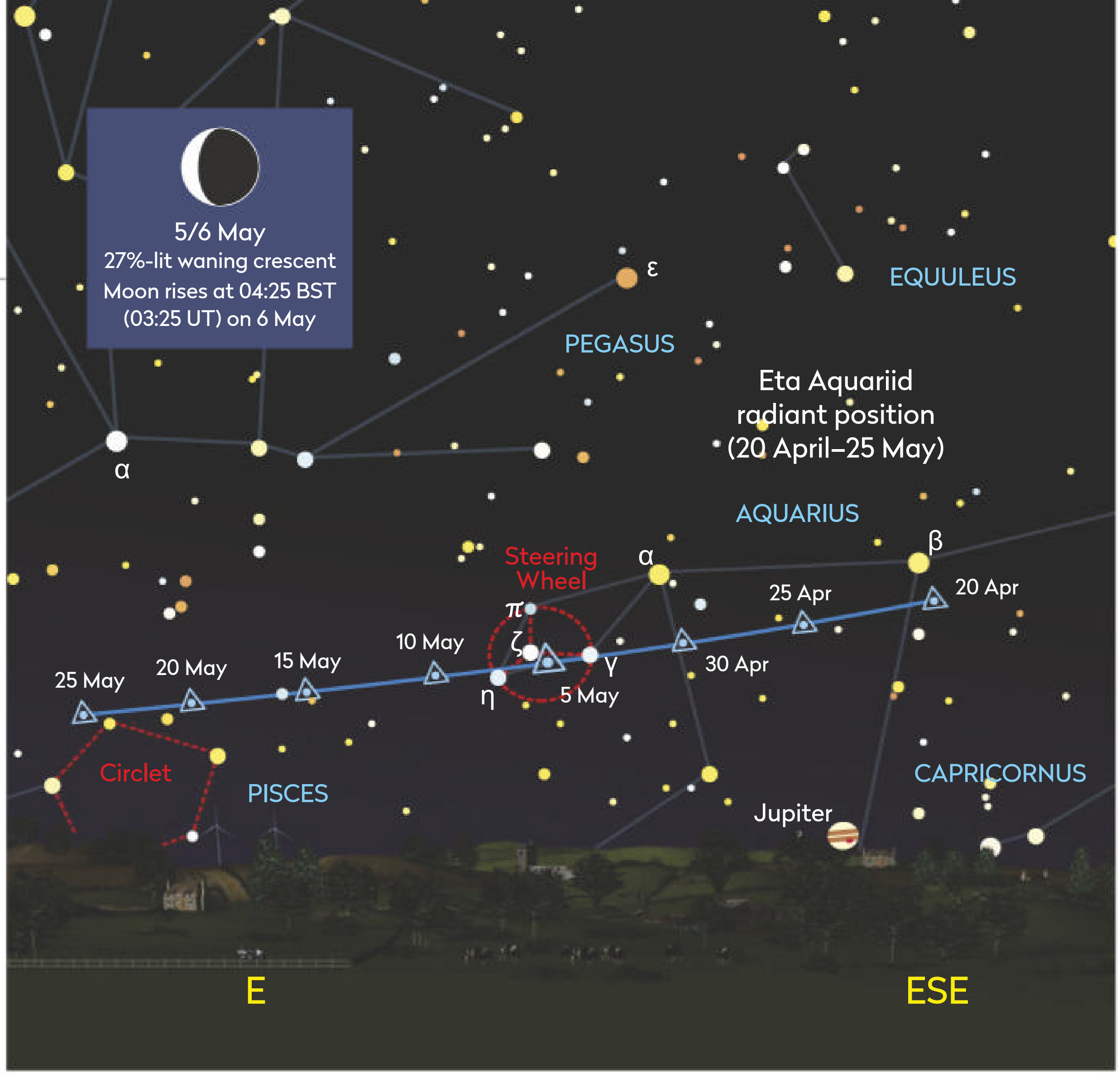
This shower is one of two annual showers caused by Halley's Comet, the second being the Orionid shower which peaks in the third week of October. The Eta Aquariid shower is best suited for Southern Hemisphere-viewing, but here in the UK it's possible to catch a few trails from it.

The radiant (the point at which the shower appears to a terrestrial observer) is located near to the Water Jar asterism in the constellation of Aquarius, the Water Bearer. In early May, this region of sky rises around 02:40 BST (01:40 UT). The nights get short in May and the onset of dawn twilight means the viewing window for the Eta Aquariids is pretty short from the UK.

With a lot stacking up against this shower, at least 2021's Moon is kind. New Moon occurs on 11 May, five days after the shower's peak. Although the waning crescent Moon sits in the early morning sky near to the Water Jar, it's significantly south of the radiant's position, not rising until dawn has really brightened the sky.

The shower is typically active from 19 April until 28 May. Meteoroids from Halley's Comet enter Earth's atmosphere at the speed of 66km/s, putting them towards the upper part of the meteor speed spectrum.

As ever, the best strategy for observing Eta Aquariid meteors is to let your eyes get well and truly adjusted to the darkness for maximum sensitivity. Find somewhere comfortable to recline back on so you are looking up at the sky at an altitude around 60°; any direction will do. Then all you have to do is wait and be patient.



▲ Peak view: the best time to catch the Eta Aquariids is at 02:30 BST (01:30 UT) on 6 May

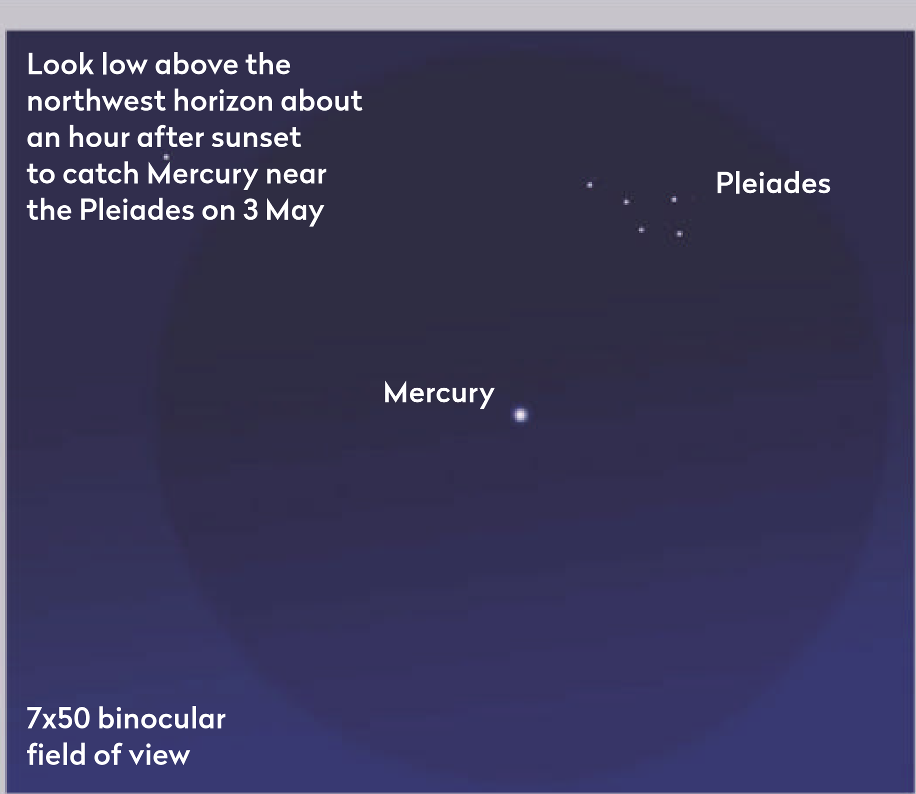
Mercury and the Pleiades

BEST TIME TO SEE: First week of May

Mercury reaches greatest eastern elongation on 17 May, separated from the Sun by 22° in the evening sky. If you have a good, flat northwest horizon, it's worth keeping an eye out for the planet as it passes beneath the Pleiades open cluster, M45. The cluster is part of the autumn constellation of Taurus, the Bull. As we're now approaching summer, Taurus is past its 'best by' date, but given clear skies it should be possible to see the brighter cluster members and the planet together.

On 1 May, mag. –1.0 Mercury lies 5° southwest of the cluster, setting around 22:10 BST (21:10 UT) as the cluster stars become visible. On 2 and 3 May the separation decreases so that by the 3rd, the mag. –0.8 planet lies 2.3° south of the cluster.

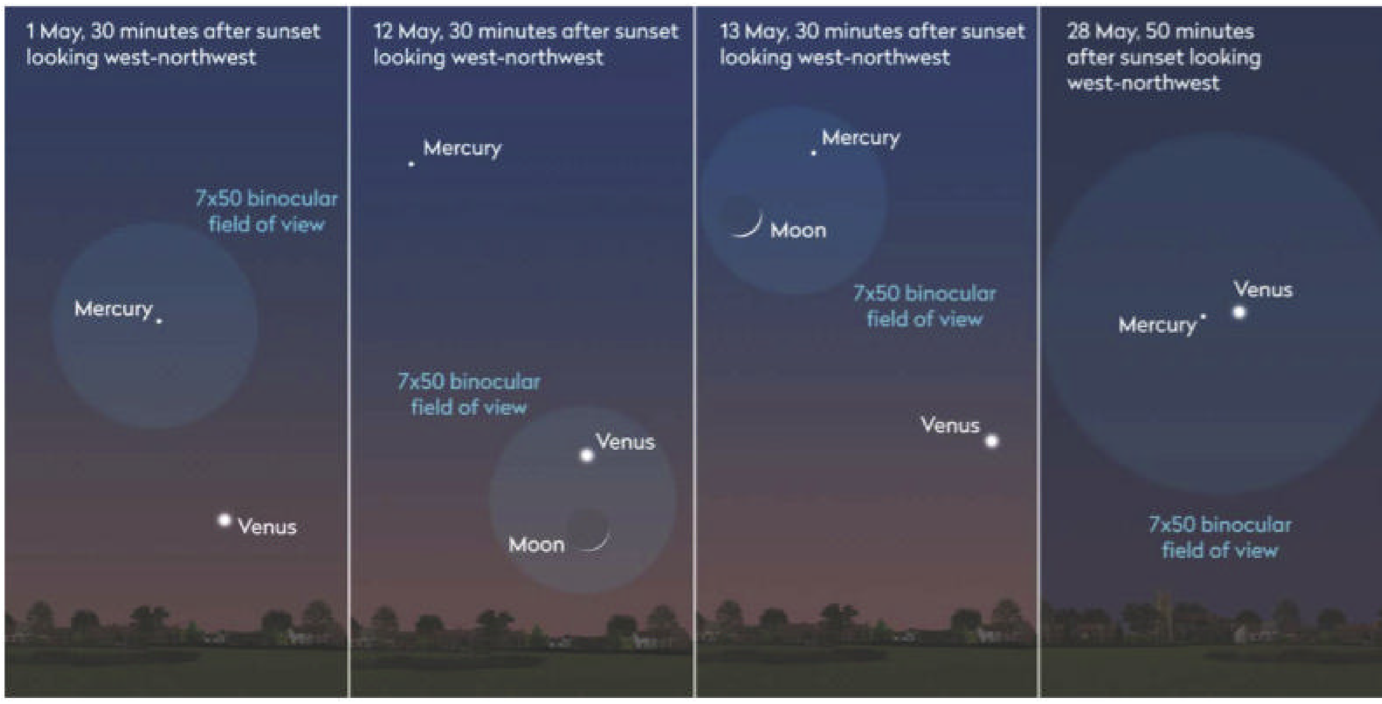
On 3 May, approximately 30 minutes after sunset, mag. –3.8 Venus also joins the show, becoming visible just 3° above the northwest horizon. Mercury can be seen above and slightly left of Venus at this time, at a more respectable 9° altitude. Venus sets around an hour after the Sun, with Mercury now clearer due to the darkening twilight, at an altitude of 5°. Use binoculars and look for the Pleiades above and right of Mercury in the same field of view as they all approach the horizon.



▲ Up close: Mercury passes beneath the Pleiades in early May

THE PLANETS Our celestial neighbourhood in May

PICK OF THE MONTH



▲ Use 7x50 binoculars to view Mercury near Venus and the Moon over the month

Mercury

Best time to see: 4 May, from 30 minutes after sunset
Altitude: 9° (low)
Location: Taurus
Direction: West-northwest
Features: Phase, larger apertures may detect surface features
Recommended equipment: 75mm or larger

Mercury is good this month, shining away in the evening twilight near its Solar System neighbour, mag. –3.8 Venus. It's a difficult call to pick a date which is the best time to see the planet. A classic balance between brightness and solar separation takes place throughout the month, Mercury appearing bright at the start of May when it's relatively near to the Sun, dimming mid-month when it's farthest from the Sun. It then continues to dim as it creeps closer to the Sun once more.

On 1 May, Mercury shines at mag. –1.0 and sets 90 minutes after the Sun. Venus will be 5° away on this date, from the UK it's visible below Mercury. On 3 May, Mercury drifts 2.3° south of the Pleiades open cluster, M45. Shining at mag. –0.8 on this date, Mercury should be seen quite clearly through the evening twilight. The Pleiades may not fare so well though!

On 13 May, Mercury will have dimmed to mag. +0.2 but should be easy to spot as it lies 2.7° to the north of a 3%-lit waxing crescent Moon. Mercury sets an impressive 135 minutes after the Sun on this date.

Greatest eastern elongation occurs on 17 May when Mercury will be at mag. +0.6. After this the planet dims but remains visible thanks to a re-approach of Venus. On 28 May, mag. +2.2 Mercury sits just 32 arcminutes from bright Venus and sets 90 minutes after the Sun.

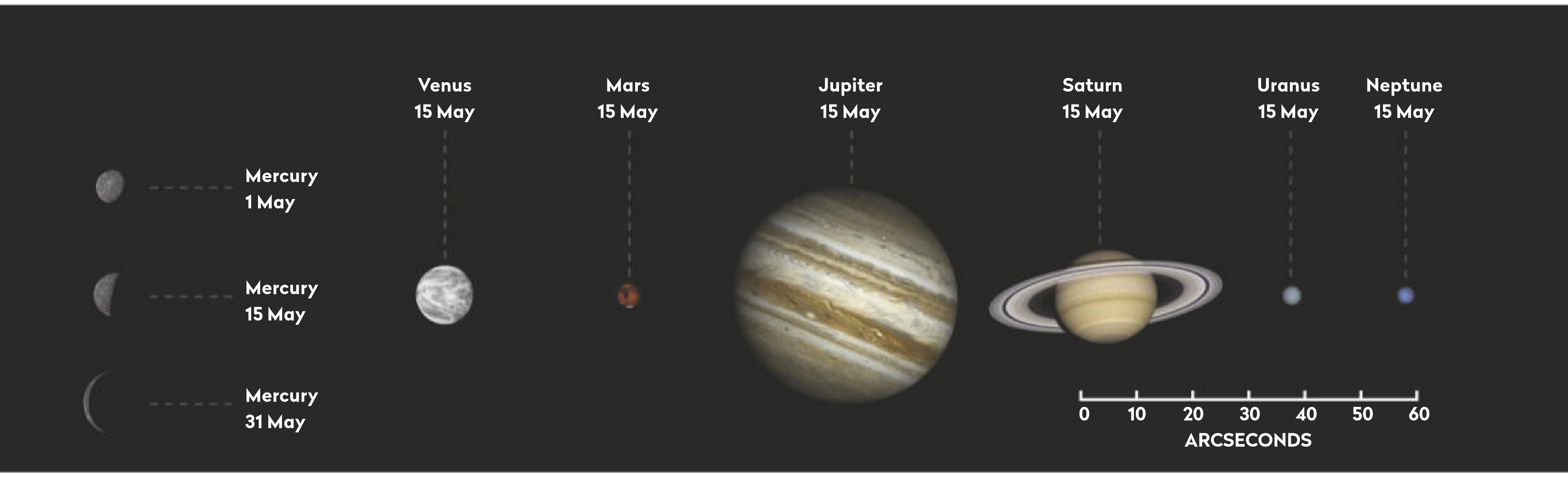
On 31 May, little Mercury will be well on its way back towards the Sun, setting just 70 minutes after sunset. At mag. +2.9 it will be a lot harder to see than earlier in the month.

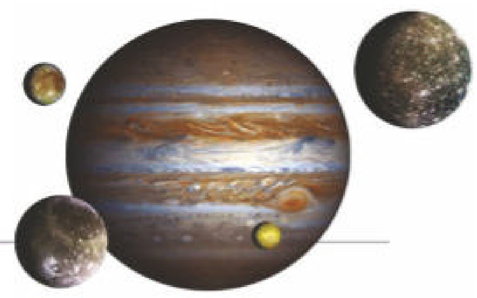
▲ Mercury and Venus will be good planetary targets during May

PETE LAWRENCE X 3

The planets in May

The phase and relative sizes of the planets this month. Each planet is shown with south at the top, to show its orientation through a telescope





Venus

Best time to see: 31 May, from 30 minutes after sunset
Altitude: 7° (low)
Location: Taurus
Direction: Northwest

Venus is an evening planet, setting 50 minutes after the Sun on 1 May and 1.5 hours at the month's end. A thin Moon, less than 1%-lit sits 2.1° southwest of Venus on 12 May. On this date Venus sets 70 minutes after the Sun. On the 28th mag. +2.2 Mercury and Venus appear separated by just 32 arcminutes.

Despite the bright evening twilight at this time of year, mag. –3.9 Venus should stand out well after the Sun has dropped below the horizon. It's on the far side of its orbit from Earth and as a consequence, through a telescope appears small – for Venus anyway – and almost fully lit with a phase that decreases from 99%-lit on 1 May to 96%-lit on the 31st.

Mars

Best time to see: 1 May, from 22:45 BST (21:45 UT)
Altitude: 21°
Location: Gemini
Direction: West

The apparent size of Mars drops further during May, from 4.6 arcseconds on 1 May to 4.2 arcseconds at the month's end. Mars also struggles to keep ahead of the evening twilight. On 1 May, Mars appears north of Castor's right foot, at Gemini's western end. It can just be seen properly against dark skies, albeit low over the west-northwest horizon.

Mars then passes through the stick-figure bodies representing the heavenly twins, to end up 5° south of the southernmost of the two twin stars in Gemini, Pollux (Beta (β) Geminorum) on 31 May. On this date, the now mag. +1.7 planet is unable to be seen against dark skies.

Jupiter

Best time to see: 31 May, from 04:00 BST (03:00 UT)
Altitude: 15°
Location: Aquarius
Direction: Southeast

Jupiter is a morning planet, reaching 14° altitude at sunrise on the 1st, rising 70 minutes before the Sun. A 35%-lit waning crescent Moon lies 5.9° south-southeast of Jupiter on 5 May. By the month's end Jupiter's visibility will have improved, the gas giant rising three hours before the Sun, reaching a 20° altitude at sunrise.

Jupiter reaches an equinox on 2 May, a time when the Sun's centre will appear on the projection of Jupiter's equatorial plane as seen from a Jovian perspective. From Earth this is a time when the four largest Galilean moons can appear to interact with each other in mutual events.

Saturn

Best time to see: 31 May, from 03:45 BST (02:45 UT)
Altitude: 15°
Location: Capricornus
Direction: South-southeast

Saturn appears as a mag. +0.7 morning object in the constellation of Capricornus. A 57%-lit waning gibbous Moon lies near Saturn on the 3rd and as a 46%-lit crescent on the 4th. The Moon then revisits on the morning of 31 May with a larger 72%-waning gibbous phase. Saturn is able to reach an altitude of 17° before it succumbs to the morning twilight at May's end.

Uranus

Not visible this month

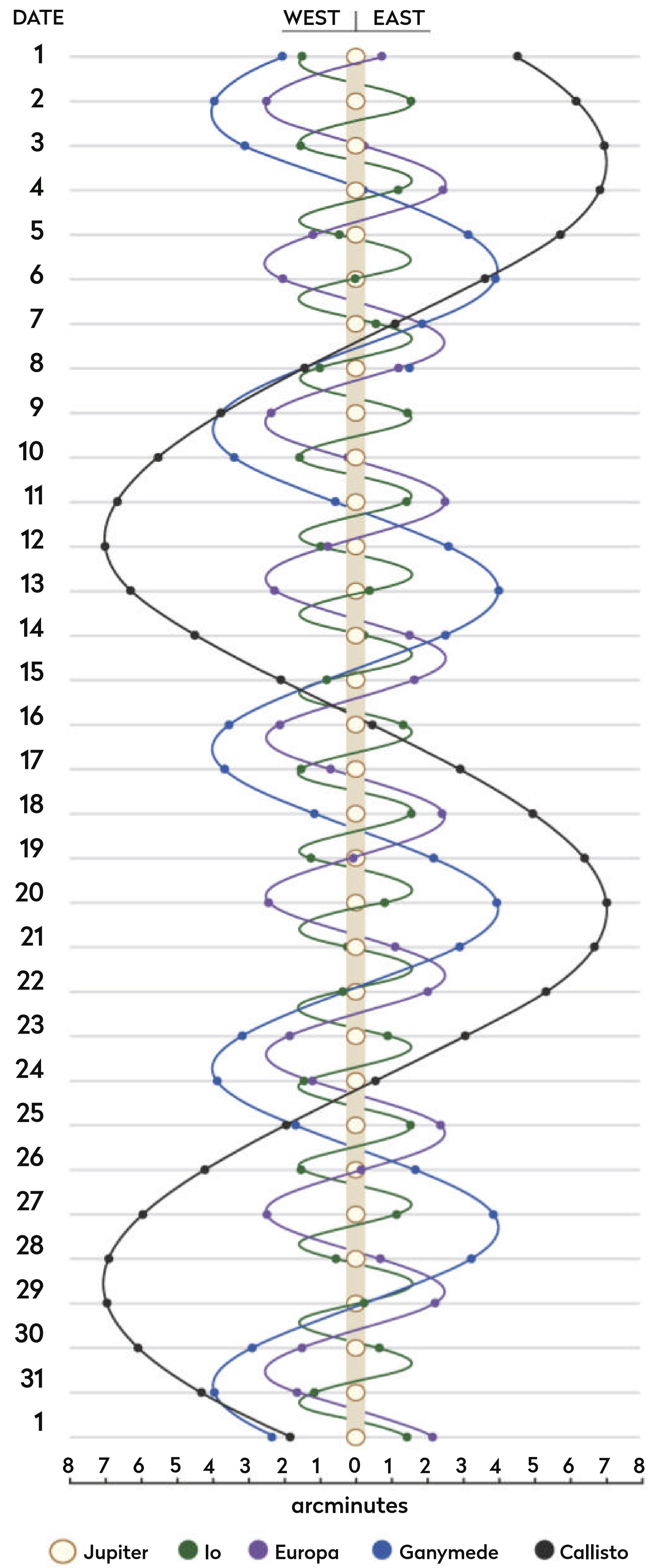
Neptune

Not visible this month

More **ONLINE**
Print out observing forms for recording planetary events

JUPITER'S MOONS: MAY

Using a small scope you can spot Jupiter's biggest moons. Their positions change dramatically during the month, as shown on the diagram. The line by each date represents 01:00 BST (00:00 UT).



THE NIGHT SKY – MAY

Explore the celestial sphere with our Northern Hemisphere all-sky chart

KEY TO STAR CHARTS

Arcturus	STAR NAME
PERSEUS	CONSTELLATION NAME
	GALAXY
	OPEN CLUSTER
	GLOBULAR CLUSTER
	PLANETARY NEBULA
	DIFFUSE NEBULOSITY
	DOUBLE STAR
	VARIABLE STAR
	THE MOON, SHOWING PHASE
	COMET TRACK
	ASTEROID TRACK
	STAR-HOPPING PATH
	METEOR RADIANT
Circlet	ASTERISM
	PLANET
	QUASAR

STAR BRIGHTNESS:

	MAG. 0 & BRIGHTER
	MAG. +1
	MAG. +2
	MAG. +3
	MAG. +4 & FAINTER
5° N E W S	COMPASS AND FIELD OF VIEW
	MILKY WAY

CHART: PETE LAWRENCE

When to use this chart

1 May at 01:00 BST
15 May at 00:00 BST
31 May at 23:00 BST

On other dates, stars will be in slightly different positions because of Earth's orbital motion. Stars that cross the sky will set in the west four minutes earlier each night.

How to use this chart

1. Hold the chart so the direction you're facing is at the bottom.
2. The lower half of the chart shows the sky ahead of you.
3. The centre of the chart is the point directly over your head.

Sunrise/sunset in May*

Date	Sunrise	Sunset
1 May 2021	05:35 BST	20:40 BST
11 May 2021	05:16 BST	20:58 BST
21 May 2021	05:01 BST	21:14 BST
31 May 2021	04:49 BST	21:27 BST

Moonrise in May*

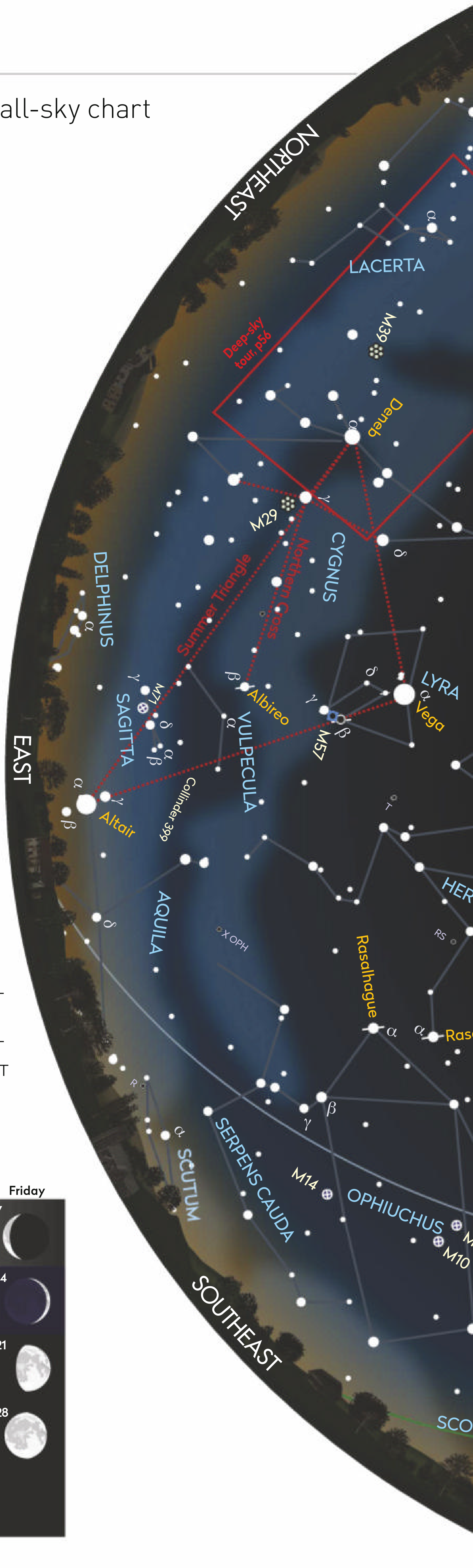
Moonrise times

1 May 2021, 01:37 BST	17 May 2021, 09:01 BST
5 May 2021, 04:08 BST	21 May 2021, 14:13 BST
9 May 2021, 05:00 BST	25 May 2021, 20:12 BST
13 May 2021, 06:04 BST	29 May 2021, 00:23 BST

*Times correct for the centre of the UK

Lunar phases in May

Saturday	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday
1	2	3	4	5	6	7
8	9	10	11 NEW MOON	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26 FULL MOON	27	28
29	30	31				



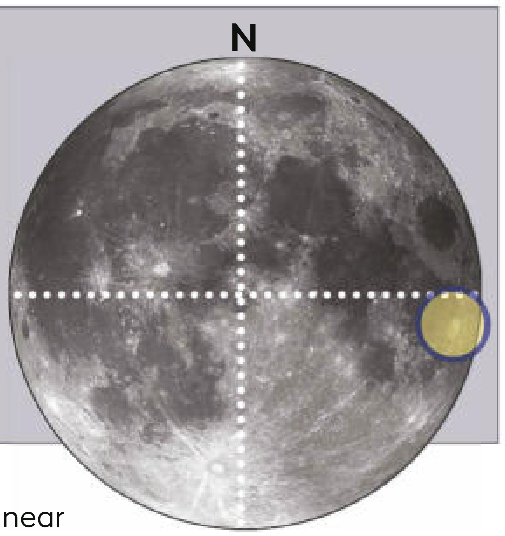
MORE ONLINE

Paul and Pete's night-sky highlights

Southern Hemisphere sky guide

Langrenus

Type: Crater
Size: 133km
Longitude/Latitude: 61˚ E, 8.9˚ S
Age: Between 1.1–3.2 billion years
Best time to see: Three days after new Moon (14 May) or two days after full Moon (28 April and 27 May)
Minimum equipment: 10x binoculars



Langrenus is a prominent crater located near to the Moon's eastern limb. As such it gets affected by lunar libration, a rocking and rolling effect caused by the Moon's orbit. Being so close to the eastern limb, from Earth, Langrenus appears foreshortened into an ellipse. Although it stays visible throughout the libration cycle, the degree of ellipticity waxes and wanes according to where the crater appears relative to the limb.

Langrenus marks the northern point of a trio of similar sized features, all located at a similar apparent distance from the limb. The middle crater is 177km **Petavius**, located some 500km further south. Continue in this direction for a further 320km and you'll arrive at 126km **Furnerius**, the least distinct of the three. The location of all three craters makes them ideal for viewing when the Moon is in its early waxing crescent phase, a part of the lunar cycle which is particularly well placed for the Northern Hemisphere during the spring.

Langrenus is quite easy to find as it sits on the eastern shore of 600km x 500km **Mare Fecunditatis**, the Sea of Fertility. This is the large, dark area which is located due south of the distinctive dark oval of 620km x 570km **Mare Crisium**.

In terms of appearance, Langrenus is a classic crater. It has a well-defined rim rising to a height of around 3km. The crater itself is around 4.5km deep. A series of complex terraces lead down from the rim edge towards a flat floor. Few features can be gained from this floor with smaller instruments, although under oblique lighting it should be possible to determine that the northern half is more rugged than that to the south. For larger telescopes or high-resolution imaging setups, a good challenge comes from trying to resolve three tiny craterlets to the southwest of the central mountain complex. These features measure 2km, 1.4km and 1.0km, arranged in descending size on a line running southeast to northwest.

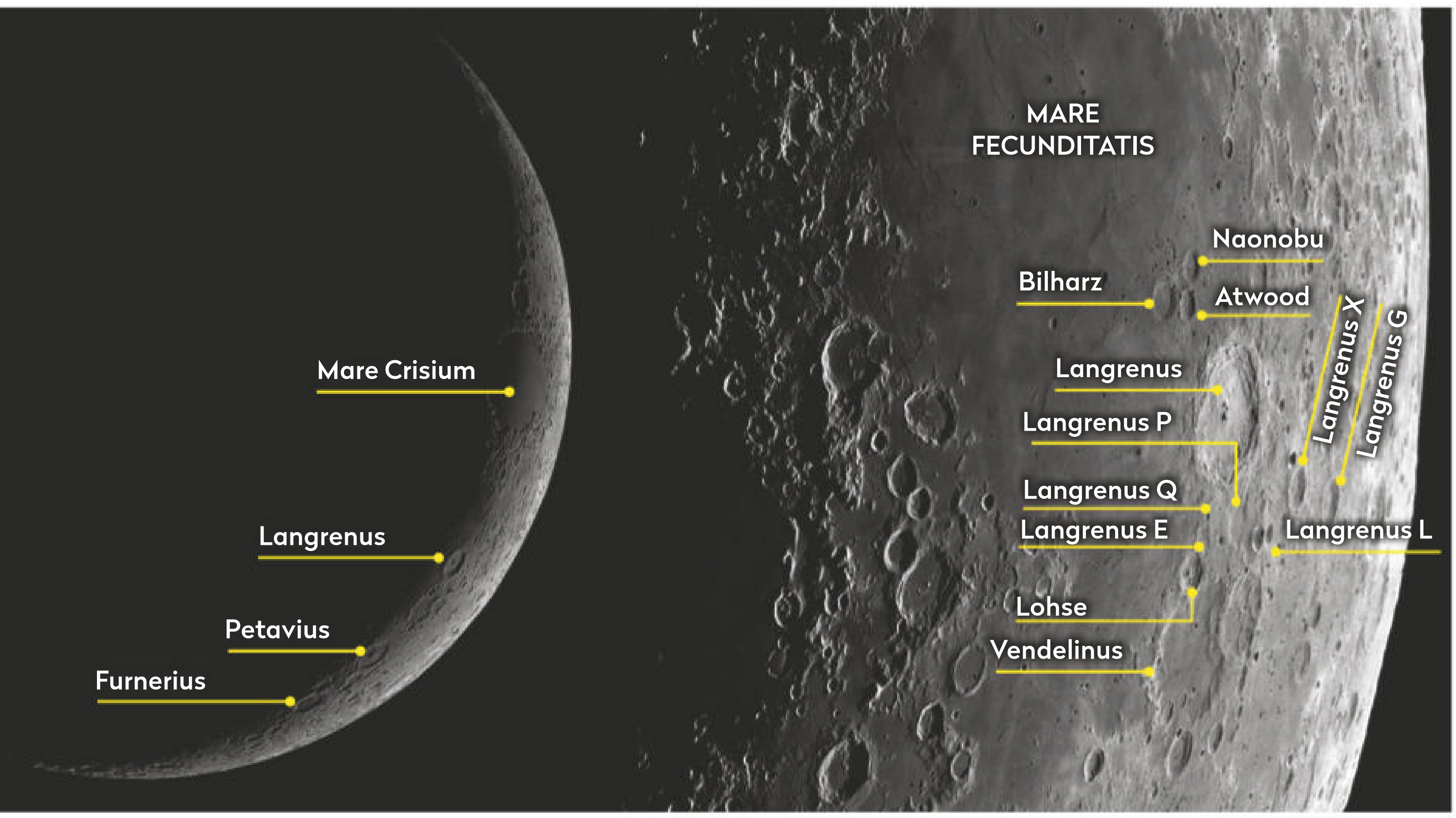
Langrenus is a classic crater with a rim rising to a height of around 3km

The dark lava of Mare Fecunditatis acts as a canvas for the impact ejecta from Langrenus. Being so close to the eastern limb, this is harder to see than, say, that of younger 93km Copernicus. In the case of Copernicus, being closer to the centre of the Moon's disc, we get to see it head on and, coupled with the fact that its features are newer than those of Langrenus, it appears quite magnificent. It's interesting to wonder how Langrenus would appear if it had a more optimised location as seen from Earth.

Head south of Langrenus and you'll pass through a bumpy region containing **Langrenus Q** (12km), **L** (12km), **P** (42km), **X** (25km), **G** (23km) and **E** (30km). After passing through this region, you'll arrive at 41km **Lohse** before reaching the ancient walled plain of 147km **Vendelinus**.

Travel 155km northwest from the centre of Langrenus and you'll arrive at a distinctive trio of small, well-defined craters arranged as a right-angled triangle. These are 43km **Bilharz** to the west, 35km **Naonobu** to the north and 30km **Atwood** marking the right-angle.

PETE LAWRENCE X 3



▼ **Locate Langrenus on the eastern shore of Mare Fecunditatis, the Sea of Tranquility**

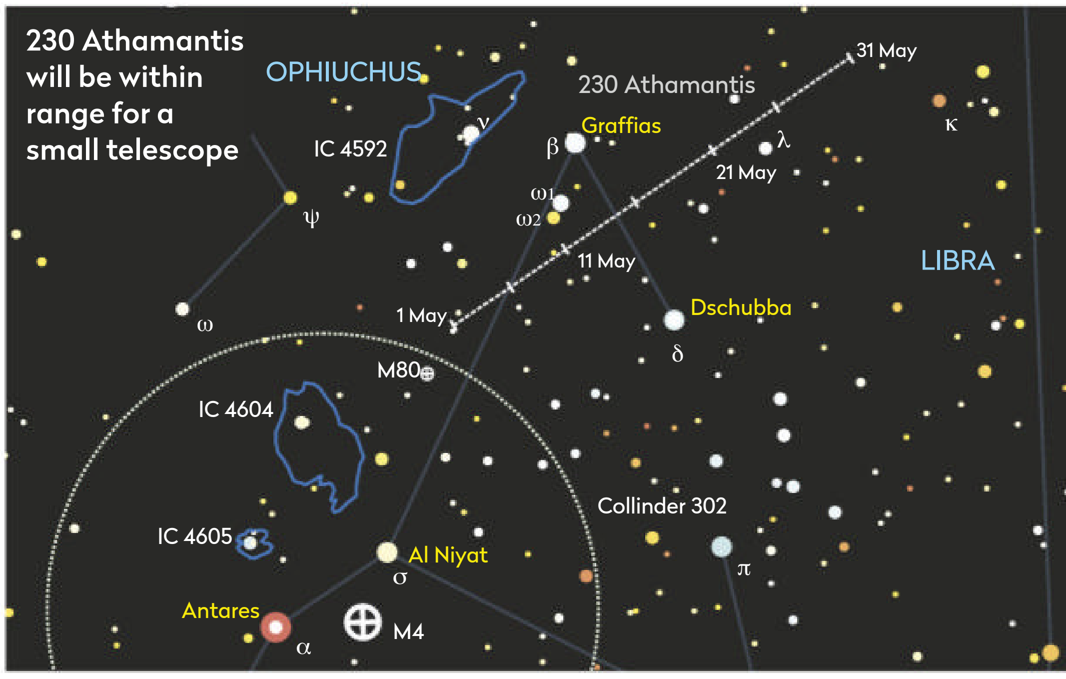
COMETS AND ASTEROIDS

View asteroid 230 Athamantis reaching opposition as it passes into Libra

Asteroid 230 Athamantis reaches opposition on 22 May, when it will appear as a mag. +10.2 object passing into eastern Libra. It's conveniently located during May, tracking from a position 1˚ northwest of globular cluster M80. This is one of two Messier catalogued globulars in Scorpius located close to Antares (Alpha (α) Scorpii). The other is M4, a globular that's larger and brighter in appearance than M80. M80 appears 10 arcminutes across and shines at mag. +7.3, while M4 appears an impressive 36 arcminutes across and shines with an integrated magnitude of +5.4.

In its position north of M80 on 1 May, Athamantis is mag. +10.9. This puts it beyond average binocular range but well within the ability of a small scope. During May, the asteroid tracks northwest, passing between the stars representing the northern claws of Scorpius; Graffias (Beta (β) Scorpii) and Delta (δ) Scorpii. It ends May less than 2˚ northeast of mag. +4.8 Kappa (κ) Librae.

Number 230 in the ever-expanding list of recorded minor planets, now numbering over a million, Athamantis was discovered on 3 September 1882 by astronomer Leo Anton Karle de Ball at the German observatory in Bothkamp, the only asteroid he discovered. It is an S-type, or siliceous asteroid, meaning it has a stony or mineralogical composition.



Athamantis has a diameter of around 111km ,which means that it's larger than 99 per cent of known asteroids. It orbits the Sun once every 3.68 years in an orbit that takes it out as far as 2.53 AU and in to 2.24 AU. It's placed between the orbits of Mars and Jupiter, making it a main belt asteroid. Analysis of the asteroid's light curve has revealed that it rotates once on its axis every 24 hours; and over this period it varies in brightness by 0.2 magnitudes.

STAR OF THE MONTH

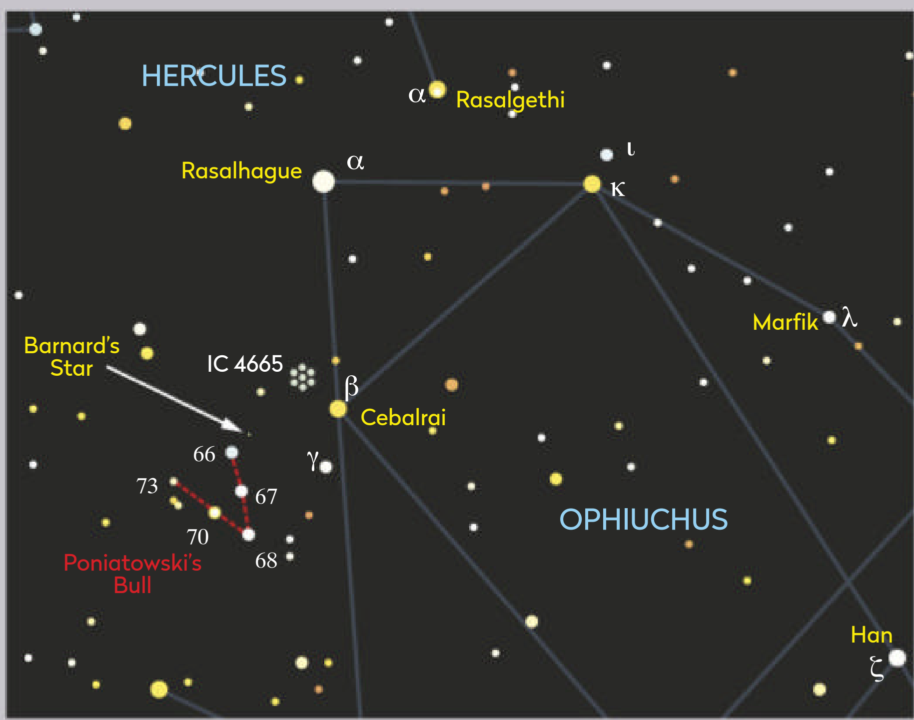
Cebalrai, at the northeast of Ophiuchus

Cebalrai, Beta (β) Ophiuchi, marks the northeast 'shoulder' of Ophiuchus, the Serpent Bearer. The star is an easy naked-eye object, shining at mag. +2.8 and appearing orange-hued. Its spectral classification is K2III; a giant star with a temperature of 4,194˚C. It's located 82 lightyears away and is 1.13 times as massive, 12.4 times larger and 63 times more luminous than the Sun. Having entered a late stage of evolution, it has become swollen in size and is probably fusing helium into carbon deep within its core. Consequently, although it's only 13 per cent larger than the Sun, its increased size is what boosts its overall luminosity.

Detailed Doppler analysis of the star's spectrum reveals three variable periods for Cebalrai, periods over which the size of the star also shows variability. The variability periods are 0.26, 13.1 and 142 days. The longer period aligns with the star's rotation period and it can be surmised that this variability is due to the passage of darker regions across its disc. The 13.1-day pulse origin is less understood.

Cebalrai sits 8.2˚ south-southeast of Rasalhague (Alpha (α) Ophiuchi). Gamma (γ) Ophiuchi lies 2.2˚ to the southeast and the open cluster IC 4665, 1.3˚ to the north, while 5.2˚ to the east is the asterism known as Poniatowski's Bull.

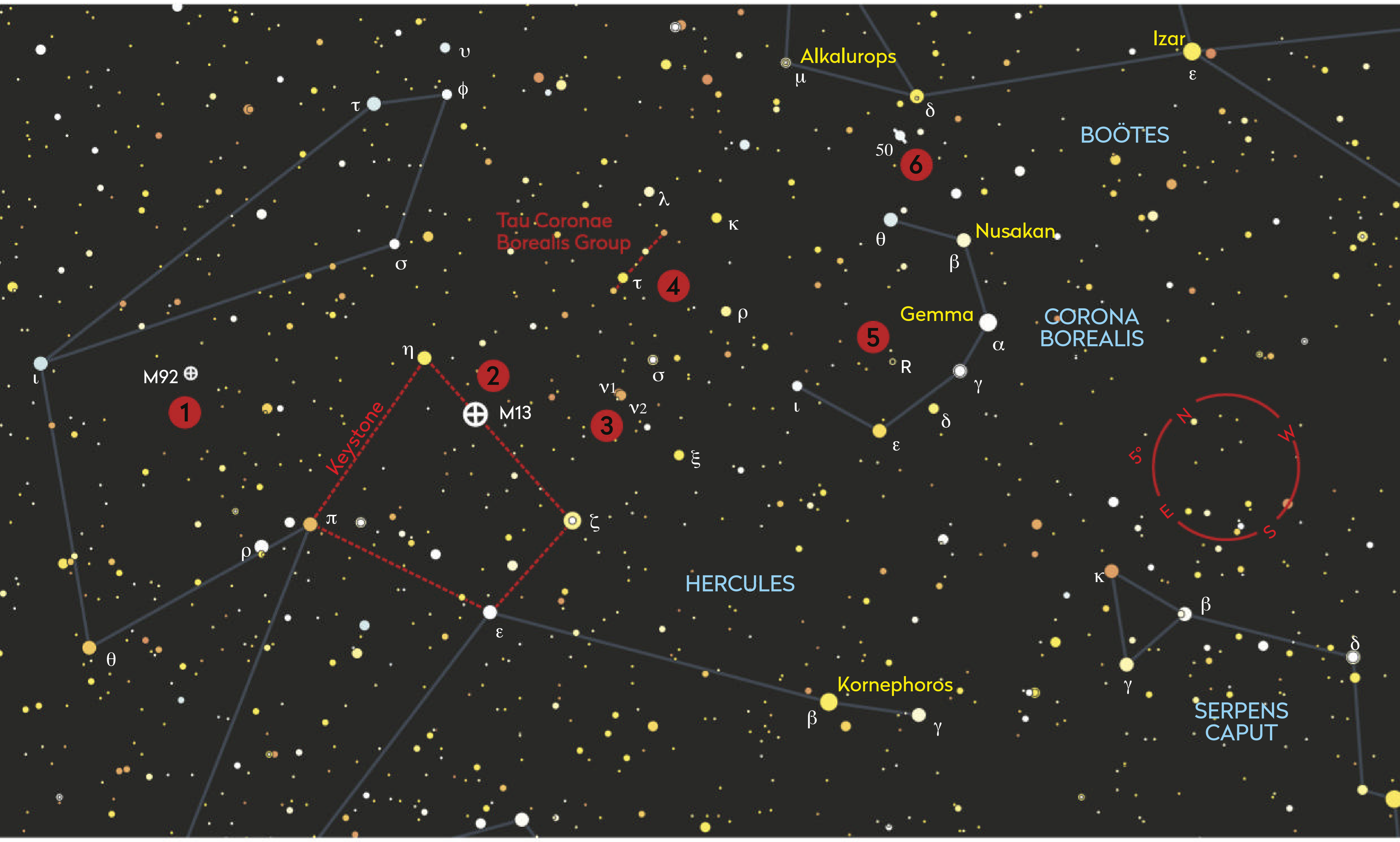
▼ **Between Cebalrai and 66 Ophiuchi is Barnard's Star**



An important star is located between Cebalrai and mag. +4.8, 66 Ophiuchi, marking the end of the western arm of the 'V' of Poniatowski's Bull. Located 0.7˚ to the west-northwest of 66 Ophiuchi is mag. +9.5 Barnard's Star, the star with the largest apparent proper motion. Over a human lifetime, it appears to move by a quarter of a degree in the sky.

BINOCULAR TOUR With Steve Tonkin

Our wide-field gems include objects near the Keystone asterism and Northern Crown



1. M92

10x 50 M92 is a fine cluster, but tends to be under-observed owing to the proximity of a more famous one. Start at Eta (η) Herculis, the northwestern corner of the Keystone asterism in Hercules, and imagine a line going northeast to Iota (ι) Herculis. Two-thirds of the way along this line, the 150,000 or so stars of M92, concentrated into an apparent diameter about one-third that of the Moon, shine at mag. +6.4. ☐ **SEEN IT**

2. The Great Cluster in Hercules

10x 50 The more famous cluster, M13, lies one-third of the way down the western side of the Keystone asterism in Hercules. You might even be able to see it with your naked eye in transparent skies. In binoculars, this globular cluster looks like a comet, brightening towards the core. This is why Charles Messier included it in his list of objects that comet-hunters should not be fooled by. ☐ **SEEN IT**

3. Nu (ν) Coronae Borealis

10x 50 Nu (ν) Coronae Borealis appears double to your naked eye and is easily split in small binoculars. The stars of this optical double (a chance line-of-sight pairing of stars that aren't gravitationally bound) are similar, both being giants with masses about 2.5 times that of the Sun, but the more distant star, Nu¹ (ν^1) Coronae Borealis, is at a later stage of evolution and more luminous than its partner Nu² (ν^2) Coronae Borealis. ☐ **SEEN IT**

4. Tau (τ) Coronae Borealis group

10x 50 Navigate 4° northwest from Nu Coronae Borealis to find Tau (τ) Coronae Borealis, the brightest star in a straight line of five stars running east-west for 2.6°. All but the central one shine brighter than mag. +6, and binoculars reveal their colours. The stars at each end are a deeper yellow than the others, while the star next to the eastern end is almost white by comparison. ☐ **SEEN IT**

5. R Coronae Borealis

10x 50 Lying in the middle of the Northern Crown is an enigmatic variable star. It usually shines at mag. +5.9, but its brightness randomly plummets as low as mag. +15, like a nova in reverse. When this happens, it does so very quickly, so it's worth watching every clear night. R Coronae Borealis is a 'sooty' carbon star; it puffs out carbon which, if it is in our line of sight, obscures the star. ☐ **SEEN IT**

6. 50 Boötis

15x 70 Our final target is a triple star. Start at Delta (δ) Boötis, a fine binary star, and pan about a degree and a half eastwards. 50 Boötis is a hot blue-white star that shines at mag. +5.3. Its two companions, which are mag. +9.5 (174 arcseconds southeast) and +10.4 (118 arcseconds northeast) are yellowish, making this a pretty group. ☐ **SEEN IT**

☑ Tick the box when you've seen each one

PETE LAWRENCE X 3

THE SKY GUIDE CHALLENGE

Can you spot Mercury with a telescope and log an observation of its phase?

Mercury is an elusive planet and one that a surprising number of people have never seen. May 2021 presents a great opportunity to correct this, Mercury being well presented in the evening sky. However, our challenge this month isn't just to see Mercury, but rather to see it through a telescope and log an observation of its phase.

Mercury reaches greatest eastern elongation on 17 May, the date when the planet appears furthest separated from the Sun in the evening sky. On this date the Mercury–Sun separation will be a very respectable 22°. However, the planet can be seen right from the start of May, as long as you have clear weather and a good, flat west–northwest horizon. On 1 May, it shines at mag. –1.0 and sets 90 minutes after the Sun. The setting difference increases as the planet separates from the Sun in the sky, but this is offset by a drop in brightness.

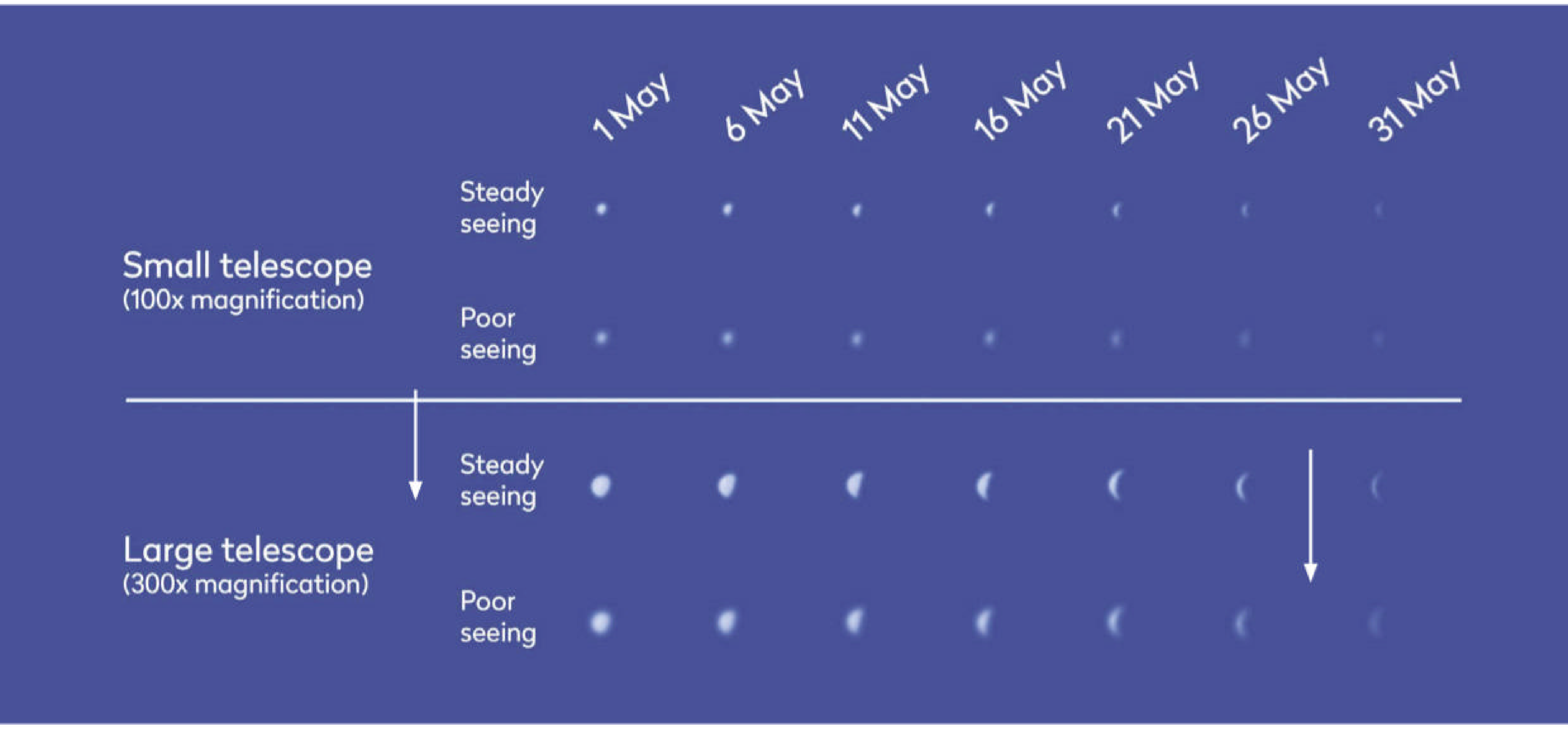
To see Mercury's phase, you'll need at least a 60mm telescope, although a 100mm minimum is recommended. We'd recommend at least 100x magnification, more if the conditions allow. For evening viewing, aim to pick up the planet as soon after sunset as possible, but of course this is also made harder because of a brighter sky. On 1 May, Mercury shows an 80%-lit 5 arcsecond disc and as the days click by, the planet dims, grows in apparent size and reduces in phase. By 10 May, setting an impressive 135 minutes after the Sun, Mercury appears at mag. –0.2, has an apparent size of 6 arcseconds and exhibits a 53%-lit phase. On 17 May, the day of greatest elongation, Mercury sets 145 minutes after the Sun, shines at mag. +0.6 and presents an 8 arcsecond disc with a 35%-lit phase.

If you manage to locate Mercury, the next trick is to turn your telescope on it

Spotting a planet and seeing its phase may sound a rather trivial challenge, but in this case, it's not. Finding Mercury can be a task in itself. Poor weather, low altitude and bright skies, will all conspire to hinder your attempts. If you manage to locate it, the next trick is to turn your telescope on it. This can be a race against time if there are features on the horizon towards which Mercury appears to be running for cover. Then there's the issue of seeing; if the seeing is poor, Mercury's tiny size may render it little more than a distorted blob through the eyepiece.

If you do manage to locate Mercury this month (turn to page 48 for positional information) and manage to catch a view of it through the eyepiece of a telescope so that you can see its phase, you can be forgiven for having a definite sense of achievement!

Under steady seeing, it's possible to see surface shading on Mercury



▲ The appearance of Mercury during May through a small (100x) and large (300x) telescope, under different seeing conditions (south is up)

DEEP-SKY TOUR

We explore the border region between the constellations of Cygnus and Cepheus

1 IC 1396

First up is the visually difficult nebula, IC 1396. Occupying a roughly circular area in southern Cepheus, the orange variable star Erakis (Mu (μ) Cephei) sits on its north-northeast edge. IC 1396 stretches 2.5° south-southwest of this star. The nebula is visually difficult due to low surface brightness. It contains the open cluster Trumpler 37 and the lovely triple Struve 2816 (Σ2816) at the region's centre.

A dark sky combined with a rich-field 150mm or larger scope will give the best results. Use a low power eyepiece and an OIII (oxygen) visual filter. ☐ **SEEN IT**

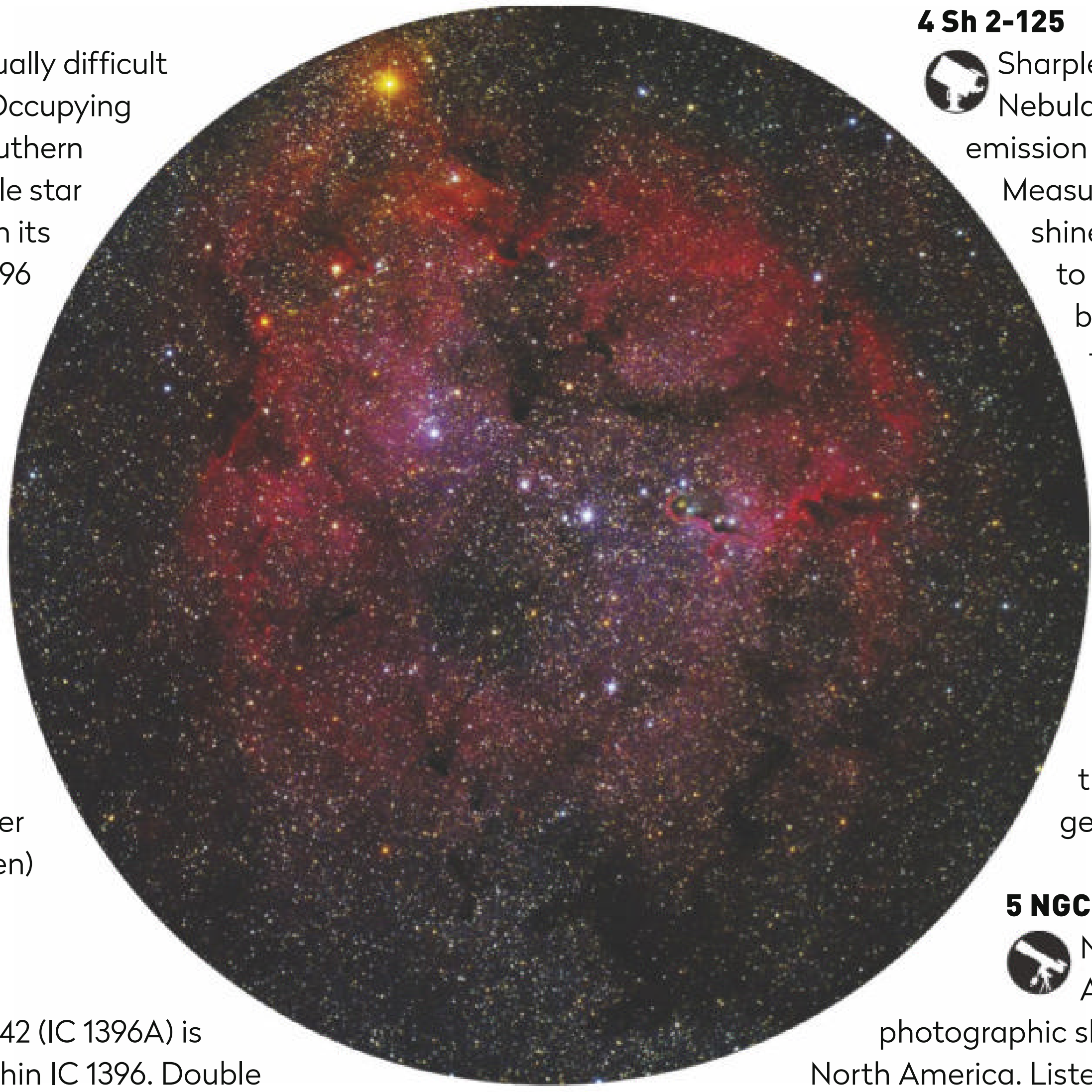
2 vdB 142

The object vdB 142 (IC 1396A) is a dark region within IC 1396. Double star Σ2813 sits centrally within vdB 142. A number of knots of brighter emission material mark the nebula's borders, especially to the west and it's this bright, thin outline that best defines vdB 142. Rotated so east is at the top, the nebula resembles an elephant's head and has become known as the Elephant's Trunk Nebula. The nebula's 'bright' outline is due to gas ionised by the massive star HD 206267, the brightest component of Σ2816. To see the outline you'll need dark skies and a large scope. ☐ **SEEN IT**

3 M39

M39 is easy to observe; first, head north of Erakis to mag. +4.3 Nu (η) Cephei and then reverse direction, moving from Nu Cephei through Erakis and continuing for around 4.5 times that distance again to arrive at M39. Mag. +4.0 Rho (ρ) Cygni lies 2.8° south of the cluster.

M39 is large at 32 arcminutes across. Visually it resembles a squashed kite. The brightest star shines at mag. +6.6. A close pair (mag. +7.7 and +8.8) sits at the centre of the pattern. At 40x magnification, the kite shape is surrounded by a field of fainter stars. ☐ **SEEN IT**



▲ **Visual rewards: for the best view of nebula IC 1396, find a dark sky and use a 150mm, or larger, telescope**

FRANZ KLAUSER/CCDGUIDE.COM, CHART BY PETE LAWRENCE

4 Sh 2-125

Sharpless 2-125, the Cocoon Nebula, is a reflection and emission nebula in northern Cygnus. Measuring 12 arcminutes across, it shines at mag. +7.2 but is tricky to see due to low surface brightness. A hydrogen-beta filter gives a better view. It co-resides with IC 5146, a cluster of mag. +9.5 stars. IC 5146/Sharpless 2-125 sits 3.5° east and 1.3° south of M39. Extending a line from mag. +4.7 Pi[1] Cygni through mag. +4.2 Pi[2] Cygni for the same distance brings you into the Cocoon Nebula's general area. ☐ **SEEN IT**

5 NGC 7000

NGC 7000, the North America Nebula, has a photographic shape resembling that of North America. Listed as a fourth magnitude object, this is misleading. With an apparent size of 120x100 arcminutes, it has low surface brightness, magnification tending to look right through it.

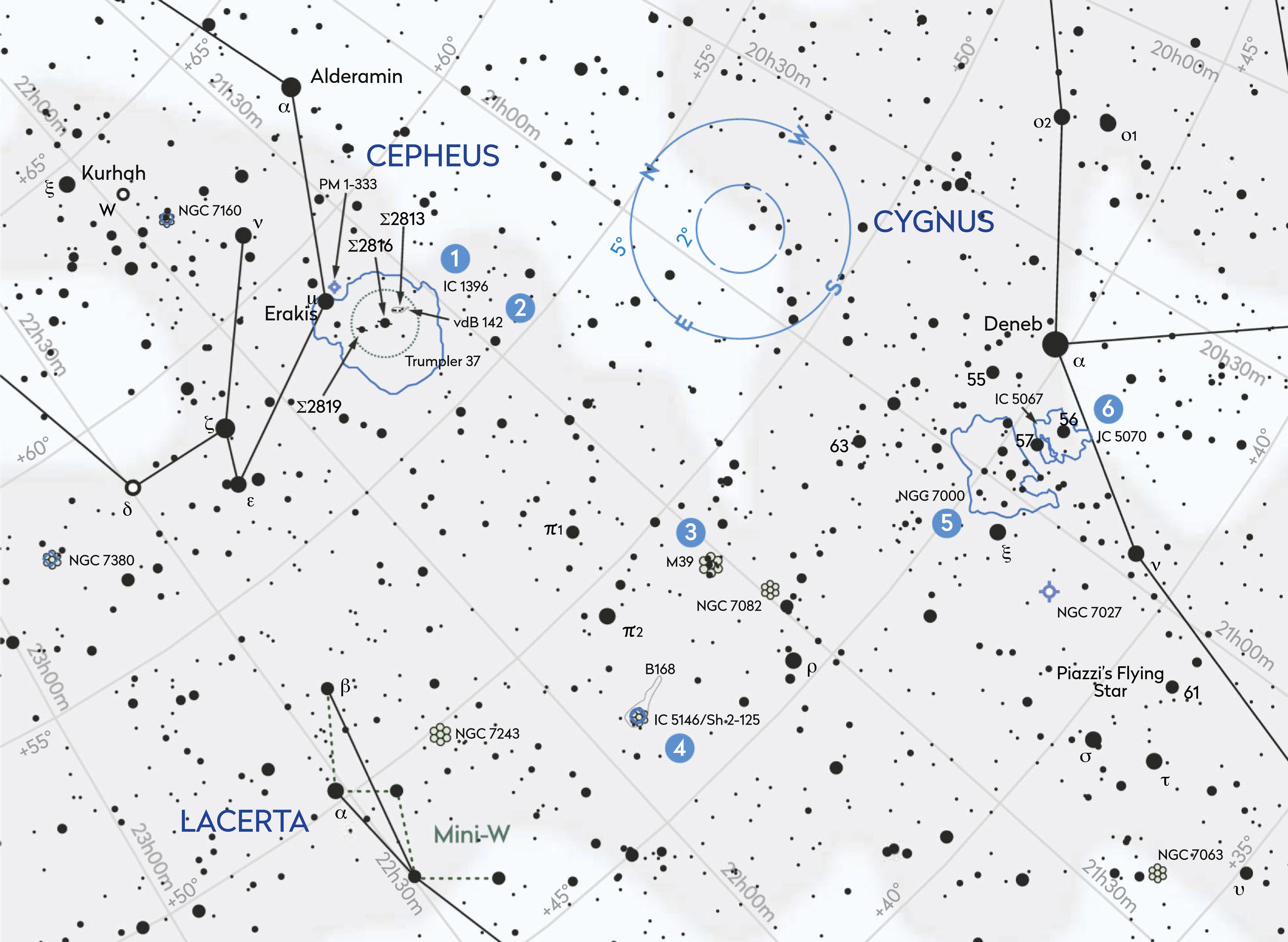
Head 4.4° east-southeast of Deneb to arrive at mag. +3.7 Xi (ξ) Cygni. Heading back along this line towards Deneb, NGC 7000's width occupies a little less than half the line's length. The southern half of the 'continent' appears brightest, a dark region forming the Gulf of Mexico providing excellent contrast with the glowing nebula. The brighter eastern edge of this region forms what's known as the 'Cygnus Wall'. The use of an OIII or UHC filter under dark-sky conditions, combined with a rich-field scope and low magnification are key to seeing any detail in NGC 7000. ☐ **SEEN IT**

6 IC 5070

If you fancy a slightly more challenging object, then IC 5070 will be right up your street. Location-wise this emission nebula couldn't be easier, because it's next to NGC 7000 to the west. It has a listed apparent magnitude of +8.0 and like its better-known neighbour NGC 7000 it's large, which leads to low surface brightness. IC 5070, also known as the Pelican Nebula, has a size of 60x50 arcminutes. The main portion (the Pelican's head and beak) sits between 57 Cygni (mag. +4.8) and 56 Cygni (mag. +5.0). The brightest part of the nebula (IC 5067), and thus the best observing region, sits slightly northwest of the mid-point of the line joining both stars. Again, a dark sky and a rich-field telescope on low power are recommended here. ☐ **SEEN IT**

This Deep-Sky Tour has been automated
ASCOM-enabled Go-To mounts can now take you to this month's targets at the touch of a button, with our Deep-Sky Tour file for the EQTOUR app. Find it online.

More **ONLINE**
Print out this chart and take an automated Go-To tour. **See page 5 for instructions.**


CEPHEUS
CYGNUS
LACERTA
Alderamin
Kurhah
Erakis
Deneb
PM 1-333
Σ2813
Σ2816
Σ2819
IC 1396
vdB 142
Trumpler 37
NGC 7160
NGC 7380
NGC 7243
Mini-W
M39
NGC 7082
B168
IC 5146/Sh2-125
NGC 7000
IC 5067
IC 5070
NGC 7027
Piazzi's Flying Star
NGC 7063
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2°
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20h30m
21h00m
21h30m
22h00m
22h30m
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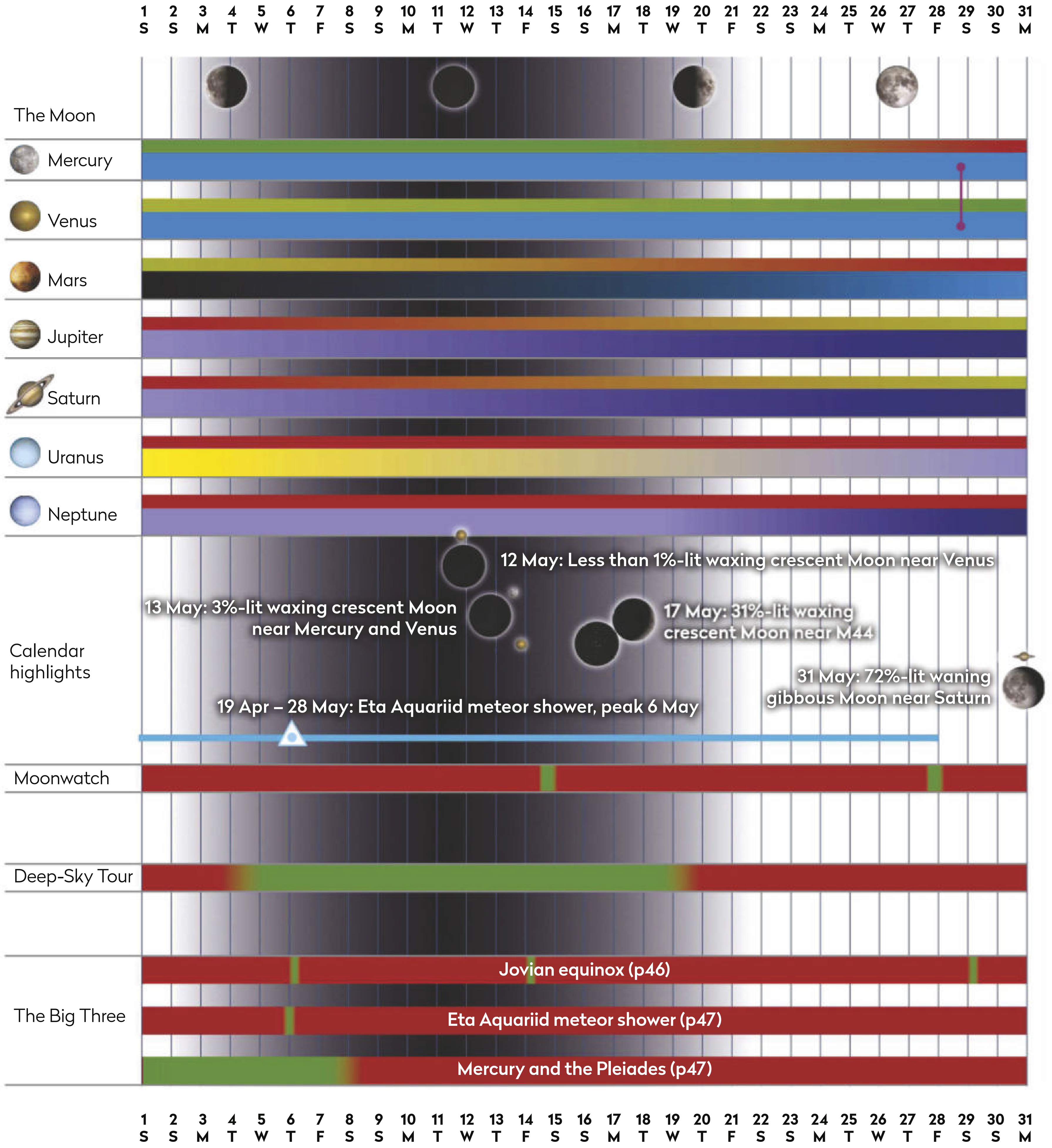
+35°
+40°
+45°
+50°
+55°
+60°
+65°

AT A GLANCE How the Sky Guide events will appear in May



KEY

Observability — Optimal | Poor

Best viewed — Morning twilight | Daytime | Evening twilight | Night

Sky brightness during lunar phases — Dark (first quarter) | Light (full Moon) | Dark (last quarter) | Total darkness (new Moon)

IC Inferior conjunction (Mercury & Venus only)

SC Superior conjunction

OP Planet at opposition

Meteor radiant peak

Planets in conjunction

Full Moon

First quarter

Last quarter

New Moon

CHART BY PETE LAWRENCE

INTRODUCTION TO ASTROPHOTOGRAPHY

A beginner's guide to DSLR cameras

DSLRs offer a simple yet effective way of capturing the night sky. **Charlotte Daniels** reveals the settings to use to get the best out of them

DSLRs (digital single-lens reflex cameras) are brilliantly versatile astrophotography cameras, and for a wide range of reasons. They perform well for most types of target, including wide-field Milky Way shots, Moon images, and deep-sky objects like galaxies and nebulae. Great for beginners, they are easy to use and can be cheap to buy, depending on the model. Plus, there's a secondhand market for entry level cameras.

DSLRs have a digital sensor and reflex mirror that directs incoming light onto the viewfinder. You can attach different lenses to them and they are also more sensitive in low light, which is important.

You can get started in DSLR astrophotography simply with the camera and a tripod, rather than jumping straight into guiding. The lenses available also provide the ability to shoot at longer focal lengths before investing in a telescope. There are also many social media groups that showcase DSLR astro images and provide support and advice.

In this guide we'll outline tips for DSLR astrophotograpy, including preferred specifications, imaging formats and key settings. A variety of Canon DSLRs are used to illustrate this feature; and you'll find that most models have a similarly recognisable array of buttons and screen settings.

Let's get technical

The two main kinds of DSLR are full-frame and crop sensor (APS-C). Full-frame DSLRs have a larger chip, giving them a wider field of view and greater sensitivity than those with a crop sensor. Some DSLRs are more suited to astro imaging than others, and the minimum requirements depend on the photos you wish to take. For example, deep-sky imaging requires a DSLR that has 'Bulb' mode. This allows you to attach a remote shutter control and shoot multiple long exposure frames. The ability to increase ISO levels is also a must (see 'Capturing deep-sky objects' section, page 64).

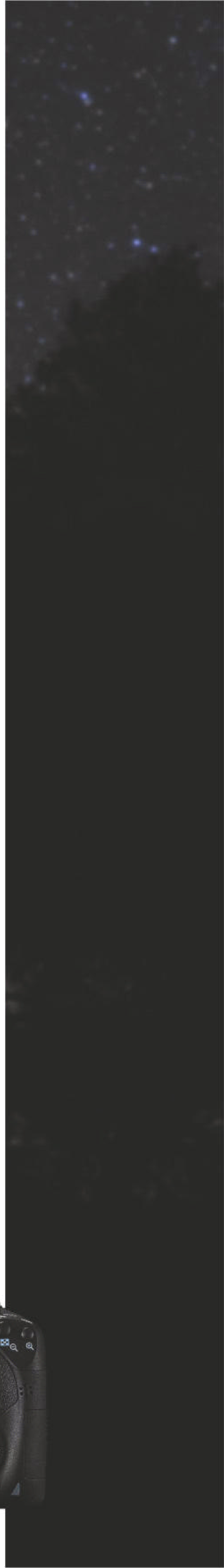
Meanwhile, lunar and planetary photography benefit most from video, as the high frame rate is better at cutting through Earth's atmosphere to produce sharp images. A DSLR with video capability is an advantage, but often a fast exposure time is sufficient. DSLRs are also great for wide-field views, because you can attach a wide, fast lens (eg f/2.8).

One thing that your DSLR requires is a 'Live View' function; this means that instead of looking through a viewfinder, the image is displayed on its digital screen (see below). This not only helps to line up an image, but means you can achieve sharp focus on stars.

In terms of physical characteristics, this is down to individual preference, but we've found that an articulated 'flip-screen' can make all types of astro imaging easier. These allow you to view frames from awkward angles, including objects overhead. This combined with a touch-screen LCD is even better, as it helps prevent you from nudging the camera.

Lastly, two rules that apply for all astro imaging are to shoot in 'Manual,' and in RAW image format, as this enhances image-editing control. We'll now take a look at what DSLRs can do, using familiar targets. ▸

▸ **Stay focused: 'Live View' enables you to look at the image on the camera's digital screen**



WILL GATER, CHARLOTTE DANIELS, CANON

Great start: a tripod is all you need to get started on imaging the night sky with a DSLR camera; the remote shutter control shown here is another useful accessory

Starting out: imaging the Moon

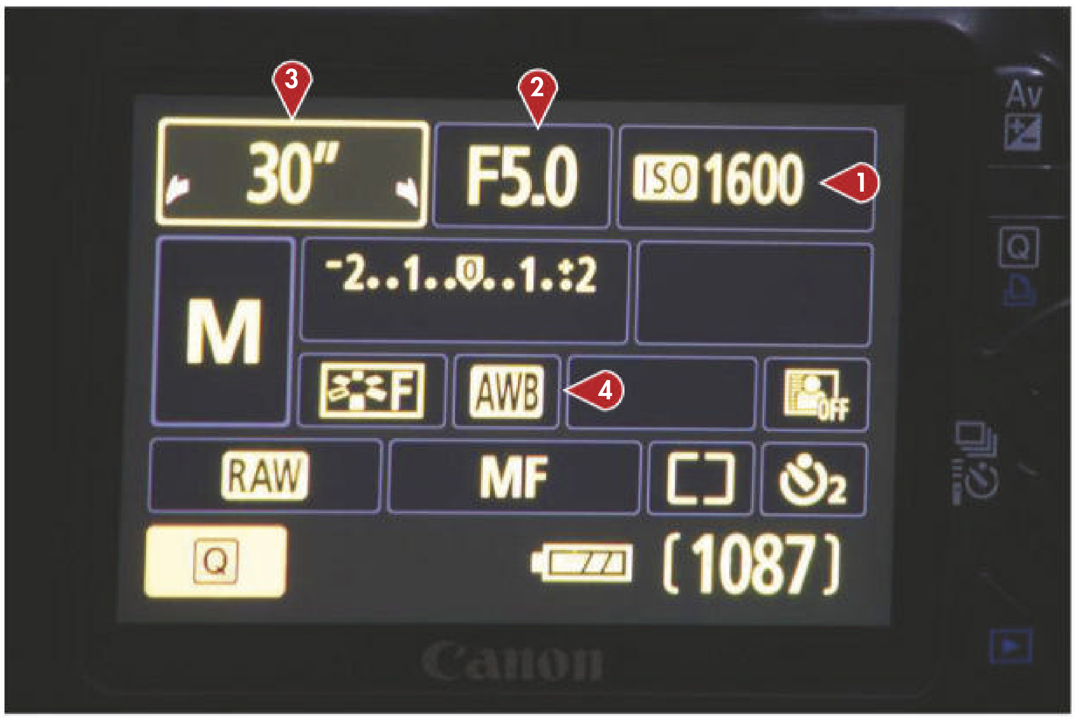
Sharper details: with the right settings a DSLR can capture lunar features in glorious detail, like this stacked and processed gibbous Moon image

The Moon is a great object to test your DSLR and get to know its settings. It's easy to find and focus on, and the DSLR can capture a lot of detail just from a single shot. For most Canon models, the 'Q' button allows you to move around the main capture settings (see our DSLR settings image on page 64). These are some of the settings to consider for lunar astrophotography:

ISO

This setting changes your DSLR's sensitivity to light and is one of the most important astrophotography settings to get used to. ISO ranges vary between models; some go from 100 to 12600 and beyond.

The lower the ISO setting, the less sensitive your camera will be to light and vice versa. However, this sensitivity is also dependant on the exposure setting: a camera on a low ISO setting but long exposure will pick up more detail than one on the same ISO setting, but with a shorter exposure time. For the Moon, which is bright, you don't want a high ISO as it will wash out the image and mean you lose detail. For Moon images, select the lowest level, ISO 100, from the ISO menu. We don't tend to use 'Auto' functions in astrophotography, instead opting to manually choose the best setting.



▲ A DSLR settings screen will include: 1) ISO; 2) Aperture/f-stop number; 3) Exposure; and 4) White balance (here on auto, 'AWB')

Aperture/f-stop number

The f-stop number that your DSLR is set at is another important factor. It affects the depth of field and how 'wide open' your camera aperture is. A low f-stop number means the aperture is wider (and is often referred to as a 'fast' setting): the DSLR will receive

▲ **Trial and error: these two lunar images, which were both taken at ISO 100 with an aperture of f/7.1, demonstrate results from trying different exposures – using 1/250 seconds (left) and 1/400 seconds (right). The Moon looks dull and less detailed in the right-hand image where the shorter exposure was used**

more light, but the depth of field in the image is shallow. This isn't important for lunar imaging, but it becomes apparent in wide-field imaging since a shallow depth of field will affect the focus of the foreground.

We don't want a low f-stop number to image the Moon because not only will it allow light to flood the camera sensor, but it will also limit lens performance. Every lens is different, however it's best to start at f/7 and work your way upwards to see what produces the best results, stopping when the image looks sharp. Both pictures of the Moon above are captured at f/7.1 aperture on a lens of 400mm, f/5.7 focal length.

Exposure

Understanding the effect of exposure time is crucial for astro imaging: depending on the brightness of the object imaged, a longer exposure usually means more detail. Deep-sky exposures can be up to 15 minutes per frame, though this depends on the camera and its sensor, which can heat up creating image noise.

Because the Moon is so bright, exposures that long would completely wash out the image, so this type of photography needs shorter frames. You want to set a length that captures the detail in darker regions without overexposing lighter areas. For our lunar image, we started at 1/200 seconds and found the image too bright. We then tried 1/250 and 1/400 and captured the two images above. 1/400 seconds was a little too fast: the Moon looks dull and less detailed, even after processing. Of all the images taken, a combination of 1/250 seconds exposure, with an ISO of 100 and and aperture of f/7.1 proved to be best for the DSLR we used, a Canon EOS 700D.

The effect of exposure time is crucial for astrophotography: depending on the brightness of the object imaged, a longer exposure means more detail

White balance

White balance (WB) is an important factor for daytime photography, but less so for astro imaging because we are shooting in RAW image format. We do this to give the most control in post-processing, so the white balance of our image can be adjusted later using photo editing software. For this reason, white balance can be left in 'Auto' mode, or 'AWB'. We can recommend Canon's 'Tungsten' WB setting, however, because it can benefit wide-field images by removing the reddish glow of light pollution.

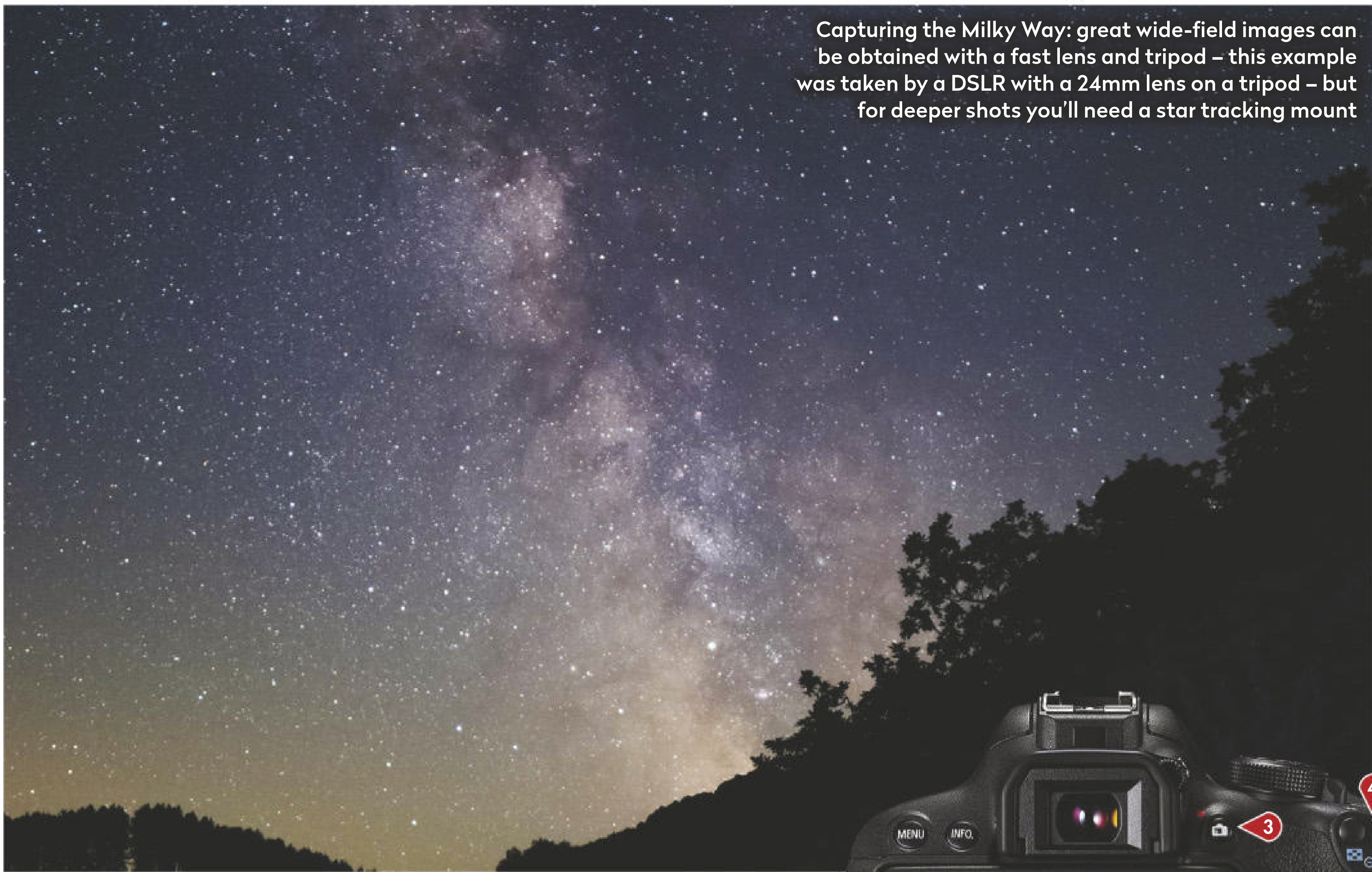
A custom white balance may be needed for astro-modified cameras. This is because once the infrared (IR) filter is removed all images have a red hue. This can still be managed in processing, but it's easier to set up a custom white balance that you can apply from the camera if imaging without filters.

Noise reduction

A common beginner's mistake is to have the noise reduction setting switched on for astrophotography, in an effort to remove the noise (unwanted artefacts) from frames. But this setting is counterproductive when imaging at night; if it's turned on, it effectively takes two photos for every exposure: a normal 'light' frame (which is your regular image), and a 'dark frame' designed to remove noise. The camera then subtracts this dark frame from the light frame, meaning each exposure takes twice as long. It's best to ensure noise reduction is switched off; on Canon DSLRs, this can be done from the main settings menu.

The best way to remove noise is to take 'calibration frames'. Dark frames are one type of calibration frame. Creating and applying calibration frames allows you to remove most forms of noise in post-processing (see 'Next steps: tracking and stacking' box, on page 65). ▸

Capturing deep-sky objects



Capturing the Milky Way: great wide-field images can be obtained with a fast lens and tripod – this example was taken by a DSLR with a 24mm lens on a tripod – but for deeper shots you'll need a star tracking mount

While it's possible to image the deep sky with a DSLR on a tripod, for the best results you'll need a tracking mount to keep track of your target as it moves with the rotation of Earth. Without one, exposure times will be limited and the process of aligning and stacking multiple image files is complicated. Here we'll look at considerations for DSLRs and deep-sky objects:

Shooting in darkness

Imaging deep-sky objects requires complete darkness. It's worth getting to know your DSLR in daylight so that you can locate buttons by feel. On a Canon, well-used buttons include 'Playback', the 'Q' button, and 'Live View' and 'Zoom' functions (see our annotated image of settings buttons found on a Canon DSLR, right). The location of these buttons varies between models and knowing them will help you to confidently set up your DSLR after sunset. In our example, the 'Live View' (3) and 'Zoom' (4) buttons help us focus, the 'Q' (2) button lets us switch between settings on the LCD display screen and 'Playback' (1) shows our test images.

One challenge is focusing your DSLR for sharp stars, and this is where 'Live View' and 'Zoom' buttons are required. Before finding your desired target, use 'Live View' to find a bright star; Vega, (Alpha (α) Lyrae), Sirius (Alpha (α) Canis Majoris) and Deneb (Alpha (α) Cygni) are popular choices. The DSLR's 'Zoom' buttons allow you to enlarge the star on your LCD screen and ensure your focus is precise.

▲ **Push the right buttons: get familiar with your DSLR camera's settings buttons. They are similar on most models, but may vary in position. In this example, the settings are: 1) 'Playback' button; 2) 'Q' button; 3) 'Live View' button; 4) 'Zoom' function**

The '500 Rule'

Imaging deep-sky objects requires far longer exposure times than the Moon, and if you are using a regular tripod the ability to capture the Milky Way or nebulae is limited by star trailing. To keep stars pin-sharp at longer exposures, a tracking mount is needed (see 'Next steps: tracking and stacking' box, opposite; and our feature on star tracker mounts in the April 2021 issue).

The '500 Rule' gives a rough maximum exposure time depending on the focal length of the lens you're using. The wider your field of view, the longer the exposure time you can apply before the stars begin to trail. If you are using a full-frame camera you divide

WILL GATER, CANON, @THESHED_PHOTOSTUCIO, CHARLOTTE DANIELS X 2, STANDRET/ISTOCK/GETTY IMAGES

◂ On the right track: we featured a guide to star tracking mounts in our April 2021 issue

Next steps: tracking and stacking

Use a DSLR with a star tracker to follow the motion of your targets, and then stack and process the results

To get the best from a DSLR, a tracking mount is needed. Most of these come equipped with 'lunar', 'solar' and 'sidereal' (star) tracking capabilities, meaning that you can image planets, the Moon, or deep-sky objects and increase your DSLR's exposure times. It also ensures the object is kept at the same place in your field of view for the entire imaging session.

A portable star-tracker or lightweight equatorial mount is a great first step. Because these mounts can track an object for hours, it means you can also stack multiple images. Stacking allows you to increase the signal to noise ratio, reducing the overall image noise. This means you can process the image data more.

A comparison between a single frame image (below, left) and stacked image (below, right) of the Horsehead Nebula demonstrates the difference that stacking can make. While the left-hand image is a single exposure, the right-hand version consists of multiple frames from the same night and same camera. The images were stacked in DeepSkyStacker (DSS) and processed in Adobe Photoshop.

Stacking images reduces much of the DSLR noise (unwanted artefacts); however, calibration frames are also important. Darks, flats and biases are each a type of calibration frame. Dark and bias frames remove electronic and sensor noise, while flat frames help remove vignetting. Dark frames can be taken before or after your imaging session: simply cover your lens or telescope and take 20–30 frames at the same ISO and exposure as the light files.

▴ Bring out the detail: a comparison between a single frame image (left) and a stacked image (right) of the Horsehead Nebula

500 by the focal length of your camera lens. For crop sensors you apply the same rule, but multiply the focal length by 1.5 or 1.6 for Nikon and Canon DSLRs respectively. If we are using a 14mm lens to shoot a wide-field image with a full-frame DSLR, we're limited to a maximum of 36 seconds per frame, but at 200mm this exposure time reduces to three seconds.

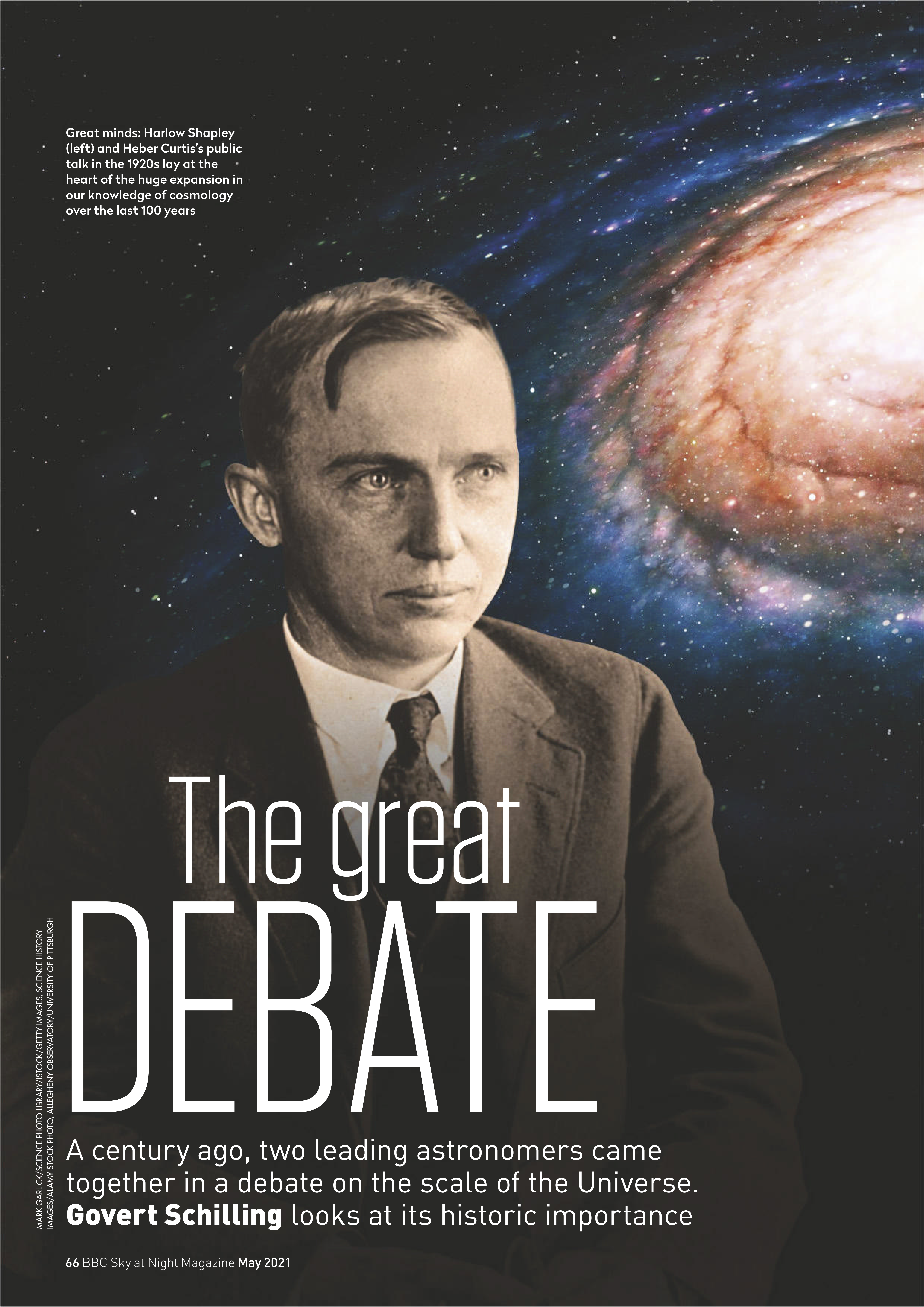
Signal noise

Managing ISO and exposure times is important for deep-sky objects, and both need to be increased for nebulae. The '500 Rule' gives the longest exposure time on a static tripod and we can increase the ISO to pick up more detail from the exposure. The best ISO performance will vary from model to model, and it's important to note that too high an exposure time will make the image noisy with a grainy appearance.

Find your camera's 'sweet spot' where you can push the ISO to boost brightness without getting obvious electronic noise. When taking your test images there are times when setting a high ISO has its benefits: we often use ISO 6400 to find and position an object before switching to ISO 800 or 1600 for an imaging run. The process of locating a faint deep-sky object with a DSLR is tricky without a Go-To mount; this will not only do the job for but it will transform your results.

Avoid noise (unwanted artefacts) in images by keeping ISO settings low

Charlotte Daniels is an amateur astronomer, astrophotographer and journalist



Great minds: Harlow Shapley (left) and Heber Curtis's public talk in the 1920s lay at the heart of the huge expansion in our knowledge of cosmology over the last 100 years

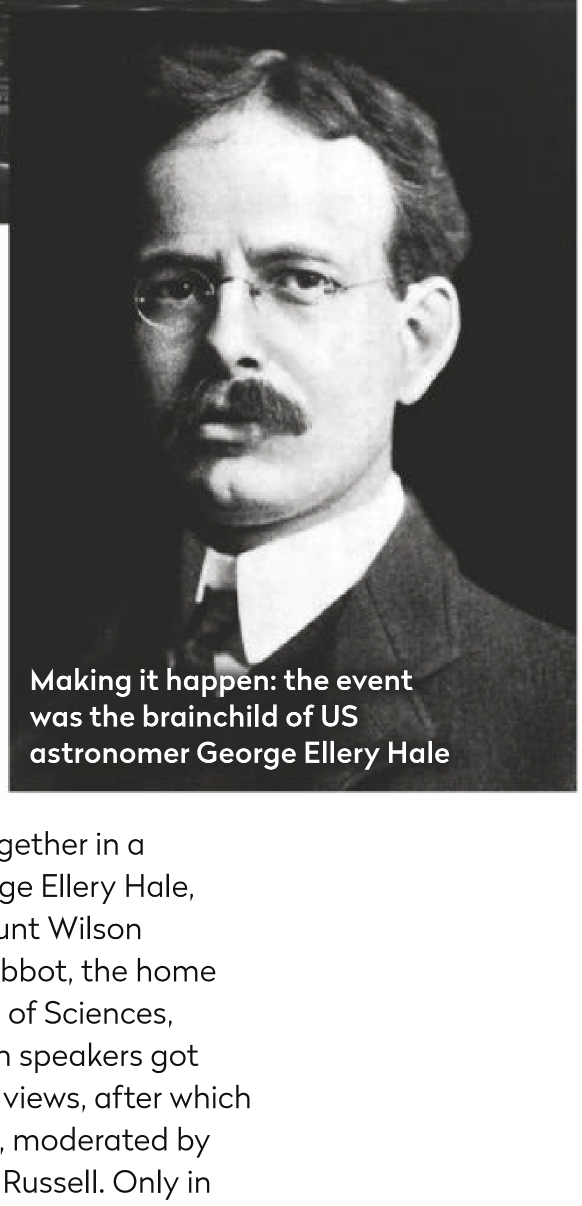
The great DEBATE

A century ago, two leading astronomers came together in a debate on the scale of the Universe. **Govert Schilling** looks at its historic importance

Mount Wilson research fellow Harlow Shapley, a 34-year-old journalist-turned-astronomer, must have been nervous when he climbed the stage in the Baird Auditorium of the Smithsonian Museum of Natural History in Washington, DC; facing him was a crowd of fellow scientists and lay people alike. On stage after him would be his opponent in the debate, eminent astronomer Heber Curtis – a man 13 years his senior, more experienced and eloquent at speaking, and who disagreed with Shapley on just about everything. The two scientists were there to argue the scale of the Universe and whether 'spiral nebulae' (what we now know as spiral galaxies) were small and nearby, or huge and far away. On Monday 26 April 1920 at 8.15pm, the historic 'Great Debate' began.

One year after the event, Shapley and Curtis presented their conflicting views in the *Bulletin of the National Research Council*. In a sense, the Great Debate was thus first published in May 1921, exactly ▸

Setting the stage: the Great Debate took place at the Baird Auditorium of the Smithsonian Museum of Natural History in Washington, DC



Making it happen: the event was the brainchild of US astronomer George Ellery Hale

▸ a century ago this month. But not many people know that the two articles were strongly expanded versions of the original presentations. Moreover, it is largely unknown that the debate mainly focused on the dimensions of our Milky Way Galaxy; that neither of the two astronomers believed that spiral nebulae were located inside the Milky Way, and that both were partly right and partly wrong. Therefore, it is time to set the record straight.

A century ago, not much was known about our Universe. Cosmic expansion hadn't been discovered yet – although a handful of spiral nebulae had had their uncannily large recession velocities measured. There was no talk of a Big Bang. Albert Einstein's new theory of gravity had only just been confirmed by the detection of the bending of starlight by the Sun during a total solar eclipse in May 1919 – but Curtis (himself an avid eclipse chaser) still didn't believe in general relativity. Moreover, no one knew about the size and structure of our Milky Way. These were the very early days of cosmology.

Going head to head

Heber Curtis, who had become director of the Allegheny Observatory in Pittsburgh, Pennsylvania in 1920, was convinced that the Milky Way Galaxy was some 30,000 lightyears across, and that the Sun was located near its centre. That view was also strongly advocated by his famous Dutch colleague Jacobus Kapteyn, on the basis of meticulous star counts. And following in the footsteps of 18th-century German philosopher Immanuel Kant, Curtis believed that many nebulae were 'island universes' – extremely remote collections of billions of stars, comparable to our home Galaxy.

In contrast, Shapley argued that observations of globular star clusters pointed toward a much larger Milky Way diameter of 300,000 lightyears, with the Sun more or less in the outskirts. If so, he told his Washington audience, "The spiral nebulae can hardly be comparable galactic systems": given their small apparent sizes on the sky, they would need to be extremely far away, contradicting a number of observations available at the time. Then again, Shapley was cautious enough to state that, "Because of the increasing activity in the nebular field, […] it is professionally and scientifically unwise to take any very positive view in the matter just now."

Bringing the two astronomers together in a public debate was the idea of George Ellery Hale, the founder and director of the Mount Wilson Observatory. Hale talked Charles Abbot, the home secretary of the National Academy of Sciences, into organising the 1920 event. Both speakers got 40 minutes in turn to describe their views, after which there was time for some discussion, moderated by Princeton astronomer Henry Norris Russell. Only in their 1921 publications did Shapley and Curtis really respond to each other's arguments.

Shapley presented a popular-level account of distance measurements in the Universe, and spent much time on observations of globular clusters, like the Great Globular Cluster, M13, in the constellation of Hercules, the Hero. Using Cepheid variable stars – which have fluctuating luminosities that are linked to their brightness, allowing astronomers to use

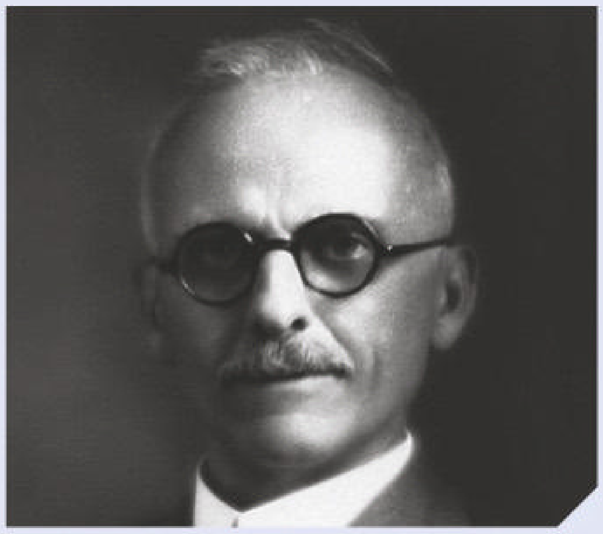
Both speakers got 40 minutes in turn to describe their views, after which there was time for some discussion

The key players

Three astronomers pivotal to settling the question of how large our Universe is

Harlow Shapley (1885–1972)

Shapley was born near Nashville, Missouri, and started out as a local newspaper crime reporter. In 1907, he wanted to study journalism at the University of Missouri, but the course had been postponed, and he chose astronomy instead. He was then hired by George Ellery Hale at Mount Wilson Observatory, and in 1921, he became Harvard College Observatory director, a position he held until he retired in 1952.



Heber Curtis (1872–1942)

Curtis earned an astronomy degree from the University of Virginia and went to Lick Observatory in 1902 to study spiral nebulae with the 36-inch Crossley reflector. In 1920, he was appointed director of the Allegheny Observatory in Pittsburgh; 10 years later, he took the helm of the University of Michigan observatories in Ann Arbor. Curtis was a member of 11 eclipse expeditions between 1900 and 1932.

Edwin Hubble (1889–1953)

Hubble studied law at the Universities of Chicago and Oxford, received his astronomy PhD at Yerkes Observatory in 1917, and served as a volunteer during World War One. In 1919, he was hired by George Ellery Hale at Mount Wilson, becoming Shapley's colleague, where he confirmed the extragalactic nature of spiral nebulae, and co-discovered the expansion of the Universe. The Hubble Space Telescope was named after him.

them to measure distances – he derived that the clusters were up to 200,000 lightyears away. Given their distribution on the sky, Shapley argued, they definitely belonged to the Milky Way Galaxy, and "There seems to be good reason, therefore, to believe that the star-populated regions of the galactic system extend at least as far as the globular clusters."

Spiral theories

But if spiral nebulae are huge collections of stars comparable to our Milky Way Galaxy, they would need to be tens of millions of lightyears away, and many of the 'new stars' (novae) in these nebulae – including the conspicuous one that was seen in the 'Andromeda Nebula' (Galaxy) in 1885 – would be much more luminous than typical galactic novae. Moreover, Shapley's Mount Wilson colleague and close friend Adriaan van Maanen, who was born in the Netherlands but moved to the US in 1911, had measured rotational motions in at least three spiral nebulae: M33, M81 and M101. If these nebulae were really huge and remote, they had to rotate much faster than the speed of light for these motions to be discernable at all.

But contrary to what you will read in most accounts of the Great Debate, Shapley did not ►



▼ **Heber Curtis's doubts about the rotational motion studies by Adriaan van Maanen – of spiral galaxies M33 (left), M81 (middle) and M101 (right) – have been proved correct**

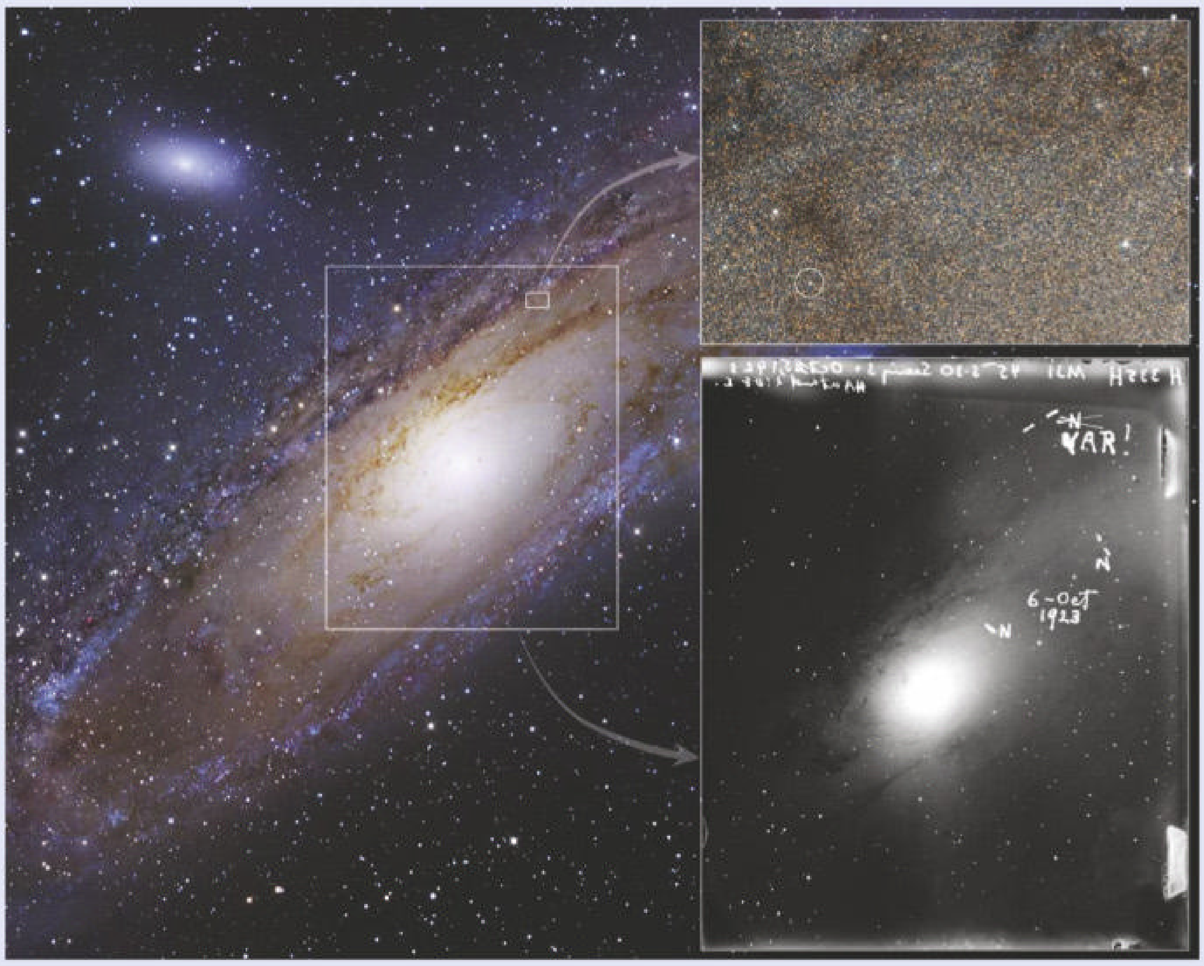
The verdict

Measurements by Edwin Hubble eventually settled who 'won' the debate

In 1921, Harlow Shapley still believed spiral nebulae to be swirls of gas in outer space. But not much later, his Mount Wilson colleague Edwin Hubble succeeded in photographing individual stars in the 'Andromeda Nebula' (Galaxy), M31. In October 1923, Hubble even discovered a Cepheid variable star in the nebula's outer parts. The true luminosity of a Cepheid is related to its period of variability, and it became immediately evident that the Andromeda Galaxy must be located well beyond our Milky Way.

In early 1924, Hubble wrote a letter to Shapley (who had moved to the Harvard College Observatory by then), saying: "You will be interested to hear that I have found a Cepheid variable in the Andromeda Nebula (M31). [...] Enclosed is a copy of the light curve, which, rough as it is, shows the Cepheid characteristics in an unmistakable fashion." According to Cecilia Payne, Harvard's first PhD student in astronomy, who was in Shapley's office when the letter arrived, he told her: 'Here is the letter that destroyed my universe.'

Heber Curtis reacted less dramatically, of course. "I have always held this view [that spirals are separate galaxies], and the recent results by Hubble on variables in spirals seem to make the theory doubly certain." Edwin Hubble had solved the central issue of the Great Debate once and for all.



▲ Clockwise from left: the Andromeda Galaxy, with the location of the Cepheid variable discovered by Hubble in 1923 (circled, top) and Hubble's own glass plate image

▸ believe spiral nebulae to be located inside our Milky Way Galaxy. Relatively nearby, yes, but, as he said, "Not members of our galactic system... I prefer to believe that they are not composed of stars at all but are truly nebulous objects." The observed novae would be outbursts of stars that were overtaken and engulfed by the nebulae; the high recession velocities would be due to some mysterious repulsive force exerted by the Milky Way.

Differing views

Curtis, who used typewritten slides to support his much more technical talk, didn't buy Shapley's globular cluster arguments, and held on to the decades-old belief of a relatively small, more or less Sun-centered Milky Way. If the 'Andromeda Nebula' was a similar-sized galaxy, it would then be some 500,000 lightyears away – not that unimaginable, although Curtis realised that the faintest ones would have to be at distances on the order of a hundred million lightyears.

In his 1921 paper, Curtis took issue with the idea of galactic repulsion being responsible for high recession velocities ("We know of no force adequate to produce such a repulsion," he wrote). As for the brightness of stellar outbursts in spiral nebulae – which was less of a problem for him, since he believed galaxies to be 10 times smaller than Shapley's 300,000 lightyears and therefore closer – Curtis presciently

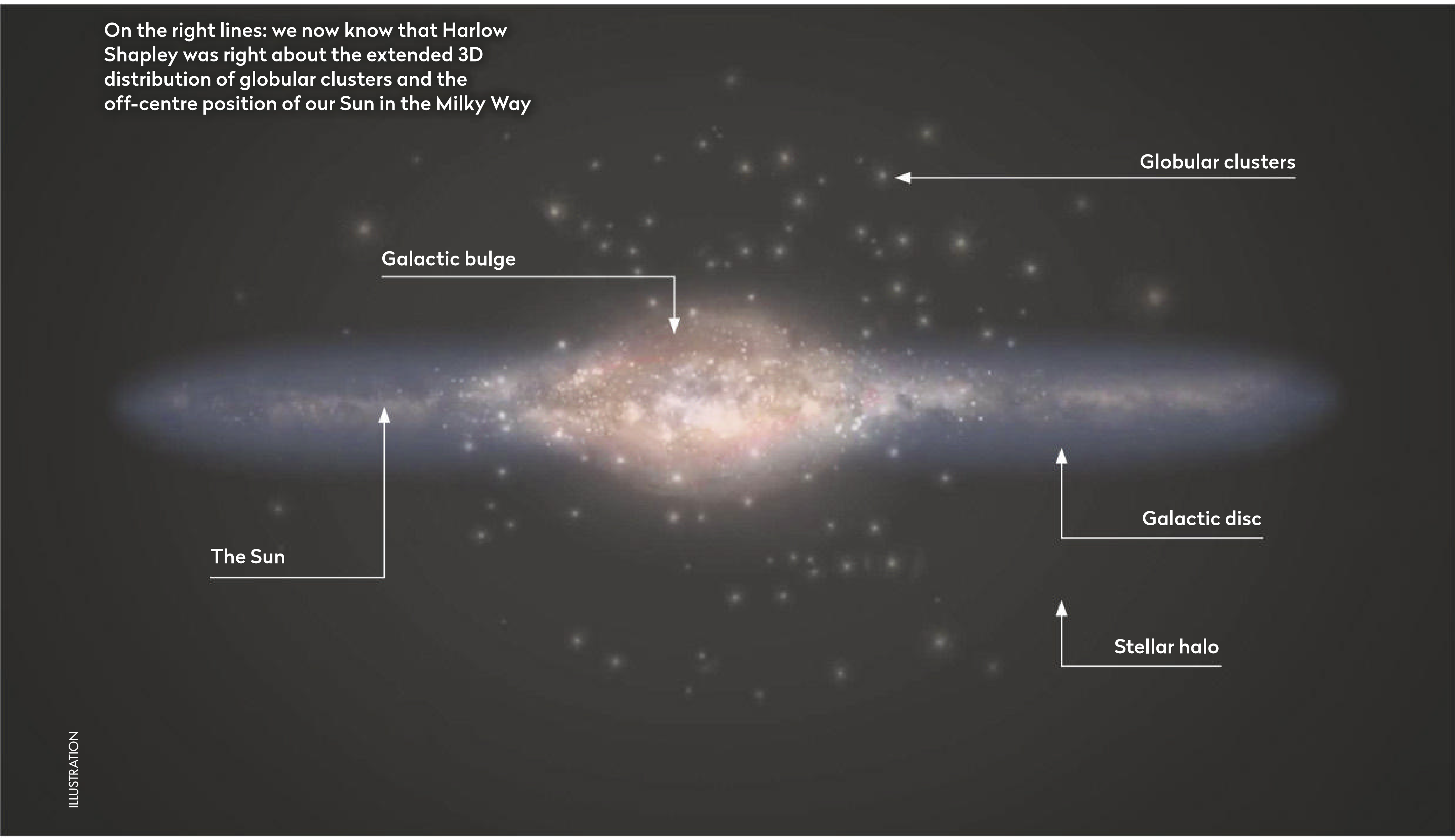
Curtis also explained why spiral nebulae were only found at high galactic latitudes – away from the band of the Milky Way on the sky

wrote: "A division into two magnitude classes is not impossible." Indeed, we now know that most of them are supernovae, which are, on average, ten thousand times more luminous than regular novae.

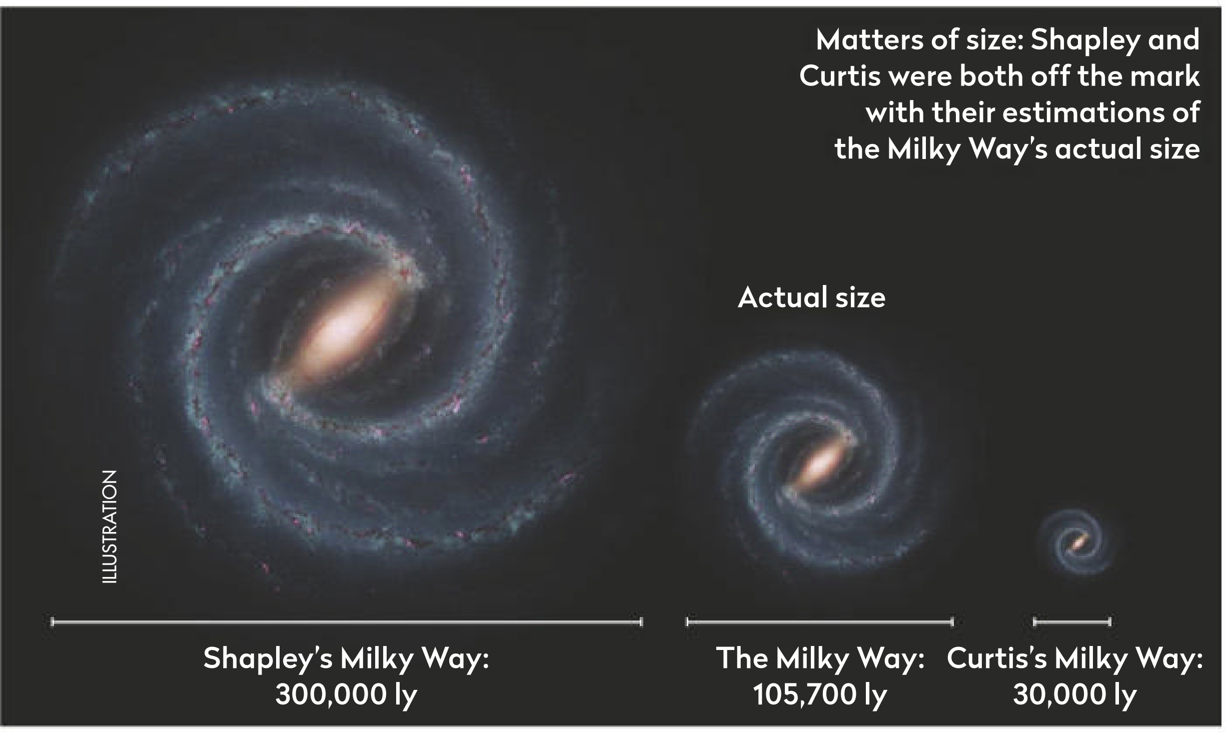
But what about the rotational motions of spiral nebulae measured by van Maanen? Well, Curtis correctly believed them to be erroneous. "I consider the trustworthy determination of the [rotational] motion [...] impossible by present methods without a much longer time interval than is at present available," he wrote, noting that if van Maanen's observations would be confirmed over "...the next quarter century [...], it would seem that the island universe theory must be definitely abandoned." No one knows what van Maanen did wrong – he was a meticulous observer – but we now know that he can never have detected real proper motions in external galaxies.

Curtis also explained why spiral nebulae were only found at high galactic latitudes – away from the

NASA/ESA AND THE HUBBLE HERITAGE TEAM (STSCI/AURA), ESA/ATG MEDIALAB, NASA/JPL-CALTECH



On the right lines: we now know that Harlow Shapley was right about the extended 3D distribution of globular clusters and the off-centre position of our Sun in the Milky Way



Matters of size: Shapley and Curtis were both off the mark with their estimations of the Milky Way's actual size

band of the Milky Way on the sky. "Many of the edgewise spirals show peripheral rings of occulting matter," he argued. "If our galaxy, itself a spiral on the island universe theory, possesses such a peripheral ring of occulting matter, this would obliterate the distant spirals in our galactic plane, and would explain the peculiar apparent distribution of the spirals." Spot on, as we now know. Ironically, Curtis didn't realise that 'occulting matter' in our Galaxy is also the reason why we get the impression of living near the centre of a relatively small, disc-like collection of stars.

Today, astronomers realise that Shapley's Milky Way Galaxy was over two and a half times too big, while Curtis's version was some four times too small and the Andromeda Galaxy is actually 2.5 million lightyears away. But while Curtis correctly assumed that spiral nebulae were individual galaxies, Shapley was right about the extended three-dimensional distribution of globular clusters and the off-centre position of our Sun in the Milky Way. As noted astronomy historian Virgina Trimble once said, "Shapley and Curtis each had hold of portions of the correct elephant." Also, interestingly enough, Shapley didn't dismiss the existence of external galaxies altogether. "Even if spirals fail as galactic systems," he wrote in his May 1921 paper, "there may be elsewhere in space stellar systems equal to or greater than ours – as yet unrecognised and possibly quite beyond the power of existing optical devices and preset measuring scales."

Less than three years later, the issue was settled and the Great Shapley–Curtis Debate became almost forgotten – it wasn't even mentioned in an obituary of Curtis, written after his death in 1942. Only in 1960 did National Radio Astronomy Observatory director Otto Struve describe it as "a historic debate", after which the event received ever-more coverage in astronomy history books. A full one hundred years after the landmark publications, the Great Debate is now a beautiful reminder of the enormous growth of our knowledge over the past century, and a testimony to the value of scientific argument.


Govert Schilling is an astronomy journalist and broadcaster, and author of *Ripples in Spacetime*

The fundamentals of astronomy for beginners

EXPLAINER

How China changed astronomy

Jamie Carter reveals how China's thirst for space knowledge traces back to ancient sky-lore

▲ The 13th-century Suzhou star chart, which features traditional Chinese astronomical groupings

Our constellations come from ancient Greek and Roman mythology. Many of the brightest stars we see – such as Betelgeuse (Alpha (α) Orionis), Deneb (Alpha (α) Cygni) and Algol (Beta (β) Persei) – were named in Arabic by Islamic astronomers. What we overlook when we gaze at the night sky is the incredible influence of Chinese astronomers.

Everyone knows about the Chinese or Lunar New Year, which starts on the day after the first new Moon that falls between 21 January and 20 February (in the Gregorian calendar) and ends with the next full Moon. You may also know about the Chinese belief that solar eclipses occur when a dragon eats the Sun. What you may not know is that Chinese astronomers were the first to make a reliable recording of a total solar eclipse (780 BC) and the passing of Halley's Comet (239 BC).

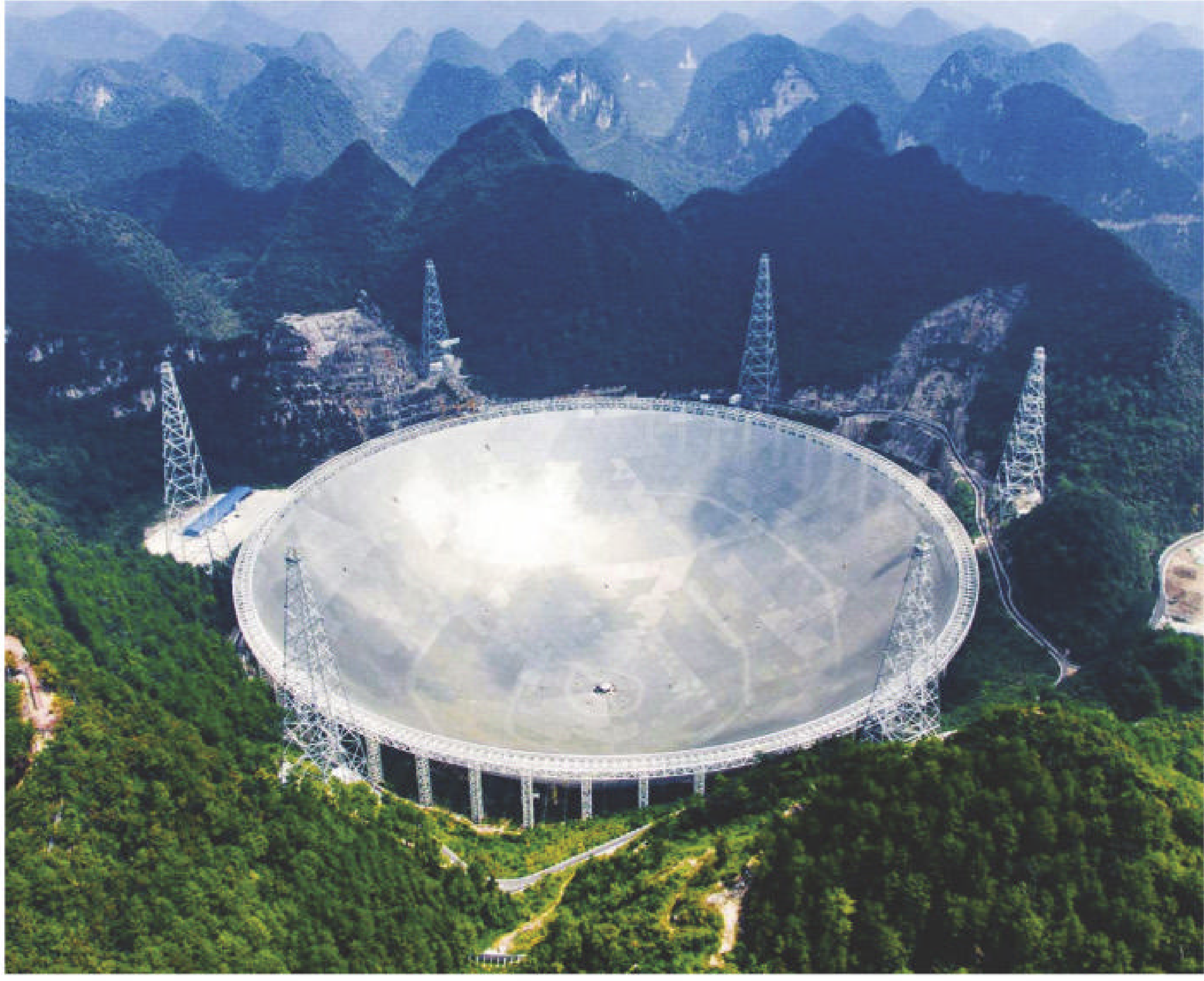
Chinese astronomers have been studying the night sky for longer than any other culture. The oldest star maps and the earliest records of sunspots have been unearthed by archaeologists in China, where a unique way of looking at the night sky developed about 1200 BC. Astronomers Gan De and Shi Shen are credited as the first to create star catalogues in the 4th century BC, and the Buddhist monk Yi Xing (below) conducted an astronomical survey in the 8th century AD to help with the prediction of solar eclipses.

China's star lore divides the sky into four groups of 283 asterisms ('xing guan'). Three of the groups are 'enclosures' of stars close to Polaris (Alpha (α) Ursae Minoris). Surrounding Polaris are the 'Purple Forbidden enclosure' (which includes Ursa Minor), the 'Supreme Palace enclosure' (including Virgo, Coma Berenices and Leo) and the 'Heavenly Market enclosure' (with Serpens, Ophiuchus, Aquila and Corona Borealis).

The fourth group comprises the 'Twenty-Eight Mansions' (groups of stars) that are themselves divided into four groups of seven symbols. Within these

► The Buddhist monk Yi Xing set up a survey across the Tang empire to help aid the prediction of solar eclipses

symbols are many easily identifiable asterisms and star clusters. For example, within the 'White Tiger of the West' symbol (which is equivalent to Taurus, the Bull) are the 'Shen' ('Three Stars') and the 'Mao' ('Hairy Head') mansions – known in the west as Orion's Belt and the Pleiades open cluster, respectively. It was in this 'White Tiger of the West' region of the night sky that, in AD 1054, Chinese astronomers saw a new and very bright star. It was a supernova, also noted by Japanese, Korean and Arab astronomers, which today we know as its remnant – the Crab Nebula, M1.



▲ 'Heaven's Eye': FAST (Five-hundred-meter Aperture Spherical radio Telescope) is the world's largest single-dish radio observatory

Grand future plans

With a pivotal place in astronomy's past, China is also poised to influence its future. Recent years have seen a growth in astronomical and astrophysical science in China. It's now the world's second most prolific nation in astronomy and space research, after the US.

That thirst for astronomical knowledge is backed-up by hardware and space missions. In 2016 the £127 million Five-hundred-meter Aperture Spherical radio Telescope (FAST) in Guizhou, southwest China, also nicknamed 'Tianyan' ('Heaven's Eye'), was opened to detect Fast Radio Bursts (FRBs) and pulsars (neutron stars formed in a supernova explosion with powerful magnetic fields). The world's largest single-dish radio observatory, FAST's importance has been accentuated by the demise of the Arecibo telescope. It looks set to become a world-class facility; astronomers using FAST have newly identified around 300 pulsars so far and want to use it to find the first pulsar outside the Milky Way. FAST will also be used for sky surveys, to search for exoplanets with magnetic fields, and to map gas clouds between stars. It will also listen for signals from any alien civilizations out there.

Even in just the last few months China's reputation among the scientific community has sky-rocketed. The China National Space Administration's Chang'e 5 mission – named after the Chinese goddess of the Moon – returned 1.7kg of samples from the Moon last December. The following month, China gave FAST an 'open sky' policy, offering up the dish to observations by astronomers worldwide. Then in February the CNSA's Tianwen-1 spacecraft arrived at Mars.

As it prepares to make China only the second country to deploy a rover on the Red Planet, the CNSA is also on the cusp of launching a modular crewed space station, the 'Tiangong' ('Heaven's Palace'). Proof, if more were needed, that China continues to have its gaze fixed firmly on the stars.

Jamie Carter is a science journalist and editor of WhenisTheNext Eclipse.com

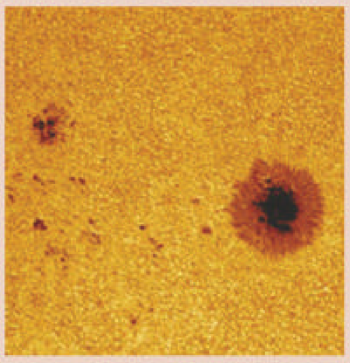
Five landmark Chinese discoveries

1. Halley's Comet: first recorded sighting

On 30 March 239 BC a sighting of Halley's Comet was recorded in the Shih Chi and Wen Hsien Thung Khao chronicles; in the 2,260 years since, every return has been recorded in China.

2. First reliable record of a solar eclipse

The 4 June 2021 will mark 2,801 years since the first reliable record of a total solar eclipse was made by Chinese observers in 780 BC. (There are etched bones with illustrations that go back further.)

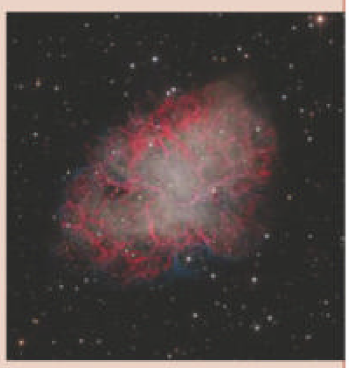


3. Earliest known observation of sunspots

Official imperial records include a mention of 112 sightings of sunspots between 28 BC and AD 1638, but the earliest recorded observations go back to 364 BC by Chinese astronomer Gan De.

4. The oldest preserved star atlas

Discovered in caves in 1900, the Dunhuang manuscript of AD 700 is the world's oldest complete preserved star atlas. Dating to the Tang Dynasty, it maps 1,345 stars in 257 constellations



5. First record of a supernova sighting

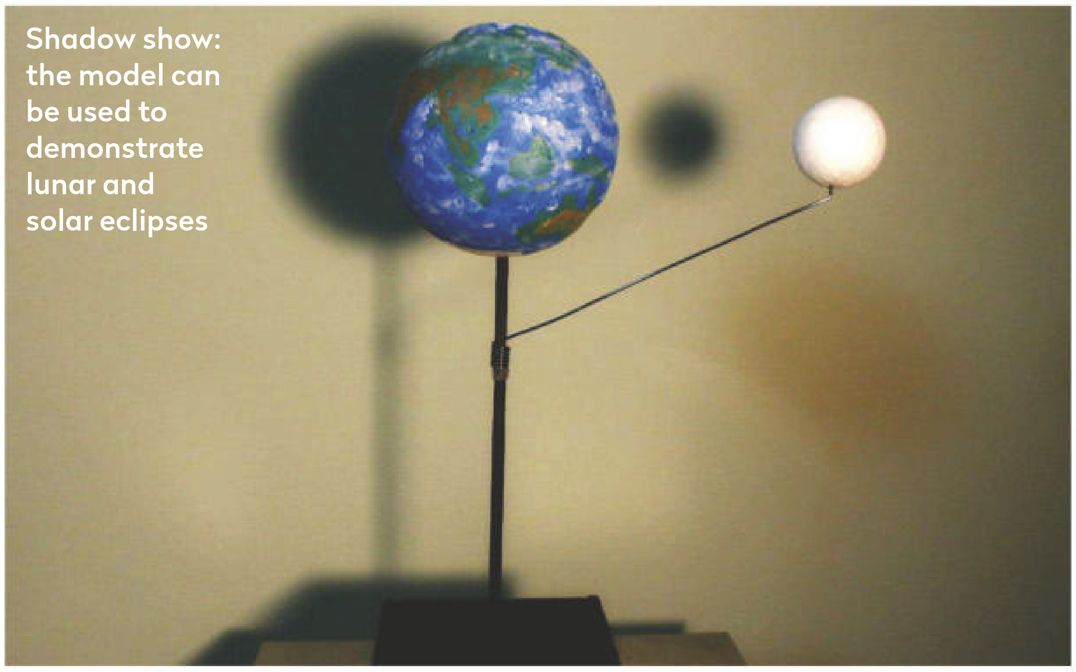
On 4 July 1054, Chinese astronomers recorded a 'guest star' in the White Tiger of the West (Taurus), which outshone Venus. The supernova remnant is today's Crab Nebula.

DIY ASTRONOMY

FAMILY FRIENDLY PROJECT

Make an eclipse shadow model

Get to know the interaction between the Moon and Earth during eclipses



Shadow show: the model can be used to demonstrate lunar and solar eclipses

Here on Earth, when the Sun shines on an object, it casts a shadow. But those shadows aren't limited to the terrestrial surface: the Moon and Earth cast shadows into space too, and as the two bodies interact with those shadows, it creates lunar and solar eclipses.

A lunar eclipse occurs when the Moon passes into Earth's shadow. This can only occur during a full Moon, when the Moon is on the opposite side of Earth from the Sun. There are two parts to Earth's shadow; the darker umbra and a slightly brighter penumbra. If the Moon passes fully into the umbral shadow, a total lunar eclipse occurs and the Moon will turn a reddish brown colour. Because Earth's shadow is so huge, a total lunar eclipse takes place over several hours. If the Moon only passes part way into the shadow we get a partial lunar eclipse.

Cast into shadow

A solar eclipse occurs when the Moon passes between the Sun and Earth. This can only occur during a new Moon. The Moon is 400 times smaller than the Sun, but the Sun is 400 times further away, so during totality the Moon perfectly covers the Sun. This allows us to view the Sun's corona, which is too faint to observe at any other time. As the Moon passes in front of the Sun, it casts a small shadow that races across Earth's surface at between 1,600 and 8,000 kilometres per hour. The Moon's shadow is also made up of an umbra and penumbra. If you are in the path of the umbral shadow you will experience totality, but this only lasts for a couple of minutes.

Eclipses don't occur every month because the Moon's orbit is tilted. From any specific location total lunar eclipses are visible about every 2.5 years; the next one from the UK is on 16 May 2022. Partial lunar eclipses are more frequent and the next one is on 19 November 2021. Total solar eclipses, however, are much rarer. The next one visible from the UK isn't until 23 September 2090, but we do get to see a partial solar eclipse on 10 June 2021.

Because eclipses can't be viewed in person that often, it is helpful to have a model that you can use to demonstrate how they work. The model also allows us to get the wider view of how eclipses look from space, rather than just from Earth's surface.

This model is simple to make and is a fun family project. It can be used to demonstrate both lunar and solar eclipses, and it shows the umbral and penumbral shadows in both cases. One thing to note is that although the relative size of Earth and Moon in our model is roughly correct, the distances are not to scale. If they were, the Moon would need to be 2.6m from Earth, and the lamp used as the Sun would need to be 1.02km away and have a diameter of 9.5m. All rather impractical at home, so we've gone for a sensible size, which will still show the theory well.

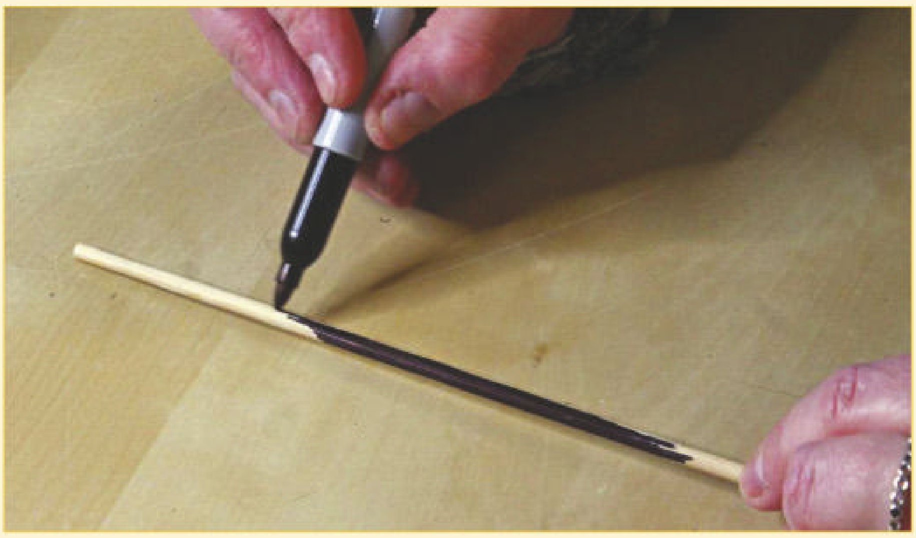
Mary McIntyre is an outreach astronomer and astro imager based in Oxfordshire

What you'll need

- A wooden barbecue skewer, the one we used had a 4mm diameter.
- Two white polystyrene balls, one with an approximate diameter of 7.5cm and one of 2.5cm.
- A small elastic band; a 25cm-length of craft wire – we used 18 gauge, which is approximately 1mm diameter. The wire needs to be easy to bend but sturdy enough to take the weight of the smaller ball.
- A small but sturdy box to act as a base (eg 7cm x 8.5cm x 4cm); model paints for Earth and a black marker pen for the skewer and base.
- An angle-poise lamp with a bendable head so you can point the light directly at the model.

ALL PICTURES: MARY MCINTYRE

Step by step



Step 1

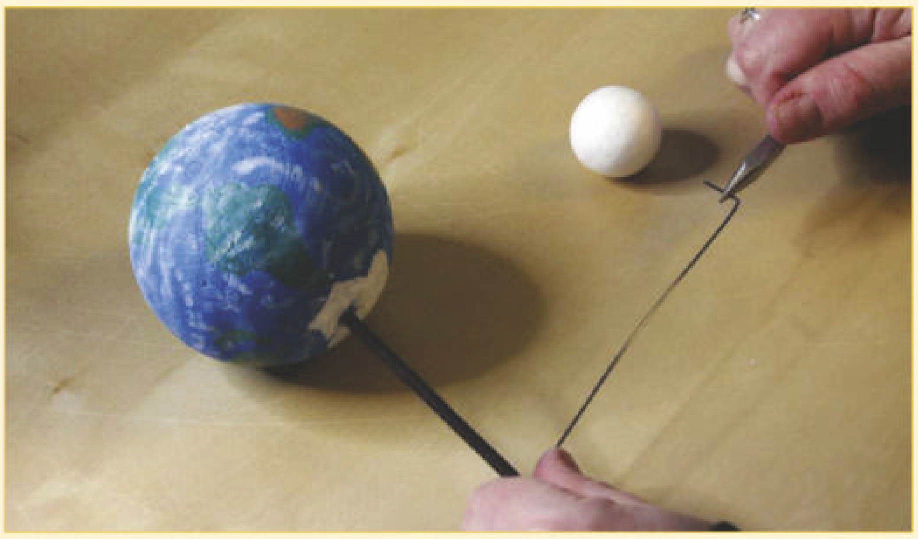
Trim the barbecue skewer to 19cm, then paint it black with paint or permanent marker. This will be the support for the larger ball – Earth in the model. It will need to be sturdy as it will also have to support the additional arm for the Moon.

Step 2

Push the pointed end of the skewer into the larger ball then paint it to look like Earth using water-based paint. This is excellent opportunity for a geography lesson, but it is up to you how accurately you want to paint the features!

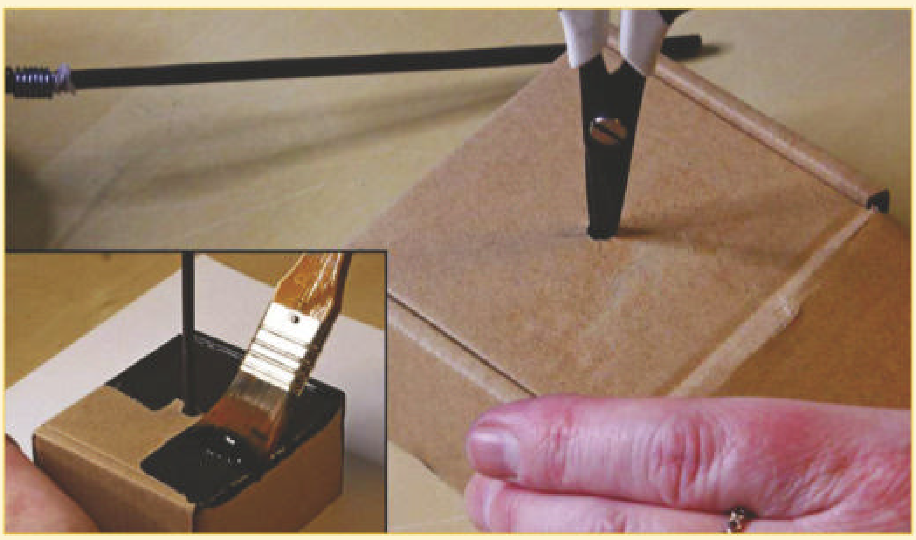
Step 3

To form the arm for the Moon, tightly wind one end of the wire six times around something slightly larger than the skewer. Slide it onto the skewer and make sure it rotates freely. Place a small elastic band 4cm below the Earth ball to hold the arm in place.



Step 4

Gently angle the remaining wire upwards; then put a bend 1cm from the other end of the wire so it is pointing straight up, and push the smaller Moon ball onto it. Make sure the Moon is in line with Earth with a 5cm gap between them.



Step 5

Make a hole about the same size as the diameter of the skewer in the centre of the box lid and push the skewer into it. Next, put a blob of Blu Tack inside the box to help to keep the skewer in place. We painted the box black for a nice finish.

Step 6

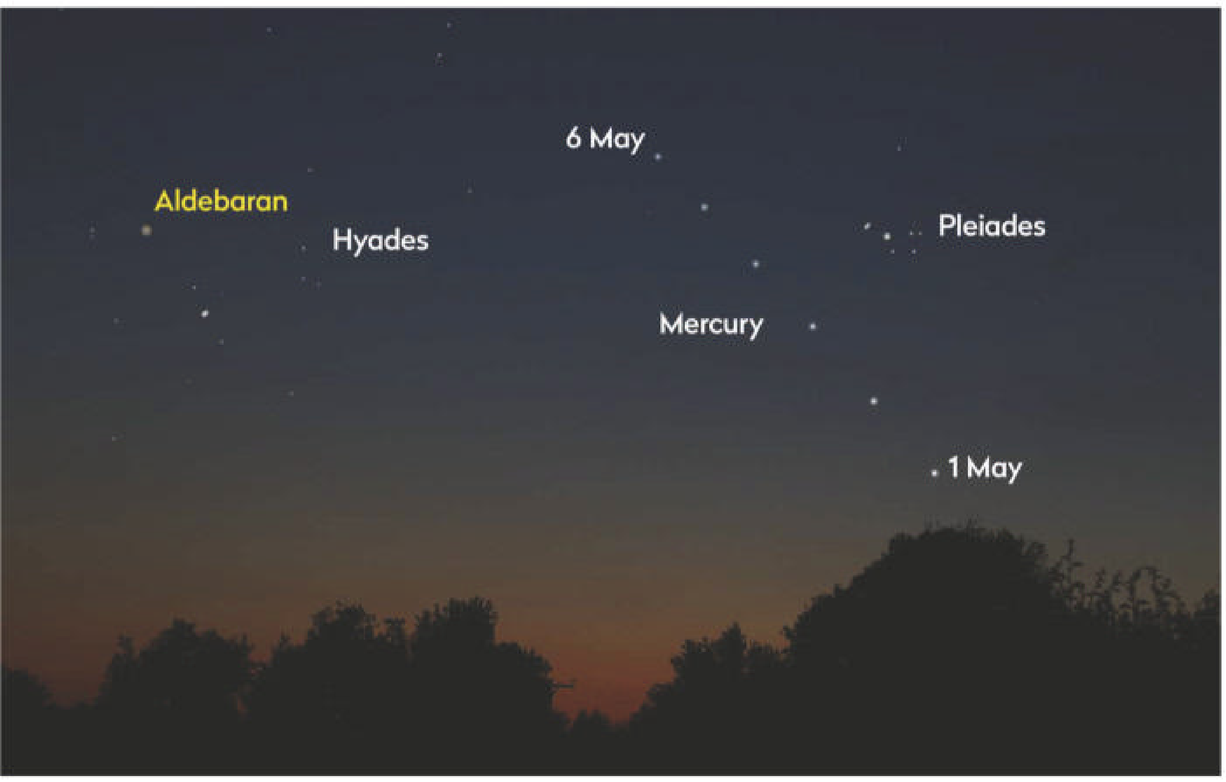
Place a lamp 25cm from the model; move the Moon in front of Earth (right) to see the lunar umbral and penumbral shadow, simulating a solar eclipse. Move it behind Earth (left) to see Earth's umbral and penumbral shadow cast on the Moon, a lunar eclipse.

Take the perfect astrophoto with our step-by-step guide

ASTROPHOTOGRAPHY CAPTURE

Catch Mercury and the Pleiades

How to image the pair low in the sky, and widen your targets to Aldebaran and the Hyades



▲ **On the right tracks: the movement of Mercury relative to the Pleiades, Hyades and Aldebaran in early May**

Mercury is well-positioned in May, joining its brighter neighbour Venus in the evening twilight above the west-northwest horizon. Together, the pair are easy to photograph due to their brightness. On 1 May, Mercury shines at mag. –1.0, Venus at –3.8.

There's an added bonus because Mercury will pass close to the Pleiades open cluster in Taurus at the month's start, which is an opportunity to image it with the cluster in the same field of view. However, there is a catch as both objects will appear low as the sky darkens enough for them to become visible. This presents a challenge for honing your astro-imaging skills, planning and executing the capture, and some post-capture processing to reveal everything clearly.

Whether you succeed will be down to several factors, the most important being the weather, the clarity of the horizon and how prepared you are. The weather does what it wants of course, but with Mercury close to the Pleiades for six evenings, at least we're not reliant on just one date being clear. The clarity of the horizon is down to you – and how easy it will be to travel in May. However, being prepared is something that can be practised beforehand, because the Pleiades will be visible in the correct part of the sky, in dark twilight, in the run up to May. Attempting to image them beforehand will allow you to gain experience in the processes involved.

Take time to experiment

A background sky that's not dark means there will be a limit to your exposure settings: set the ISO too high or exposure time too long and you'll get an overexposed sky in the background. Again, this is something that you can experiment with. Begin with a lowish ISO value, say something in the 200–800 range; a lower range will give you better tonal quality in the image.

A fixed tripod should suffice, although a driven equatorial mount will work too and make life easier. If using a driven mount, set the ISO low, use an f-stop number in the mid-range and aim for an exposure of several seconds. The low ISO will keep the image quality high while the stopped down aperture of a mid-range f-stop keeps stars and planets sharp.

As ever, select a lens that will give you optimal coverage. If you're after the Pleiades and Mercury alone, a long frame dimension of 8–10° is best. For a non-full frame (APS-C) camera, a lens with a focal length less than 125mm is ideal. On a full-frame camera, a 200mm lens will achieve the same coverage. If you want Aldebaran and the Hyades in shot, a long-dimension of 18° is recommended. Here, the lens requirements are 70mm (non-full frame) and 110mm (full frame).

The magic here comes from post-processing. If you get a shot showing Mercury with a barely discernible view of the Pleiades, it should be possible to tweak the final image into something looking reasonable.

Pete Lawrence is an expert astro imager and a presenter on *The Sky at Night*

Recommended equipment: DSLR, lenses, tripod or a driven equatorial mount, remote shutter release

Send your images to: gallery@skyatnightmagazine.com

ALL PICTURES: PETE LAWRENCE

Step by step

STEP 1

Your lens size is determined by the scene you want to image. Here, it's either Mercury and the Pleiades, or Mercury, Aldebaran, the Hyades and the Pleiades. For non-full frame cameras select a 125mm lens for the narrower scene, or a 70mm for the wider one. For a full frame DSLR, the lens sizes are 200mm or 110mm.

STEP 2

Find a location with a flat horizon from west through to northwest. If you're feeling adventurous a well-placed tree or building could be used to add drama to the shot, but be sure the feature doesn't cover any of your targets. In the run up to your attempt a test shot of the Pleiades and Hyades as they approach setting can be useful.

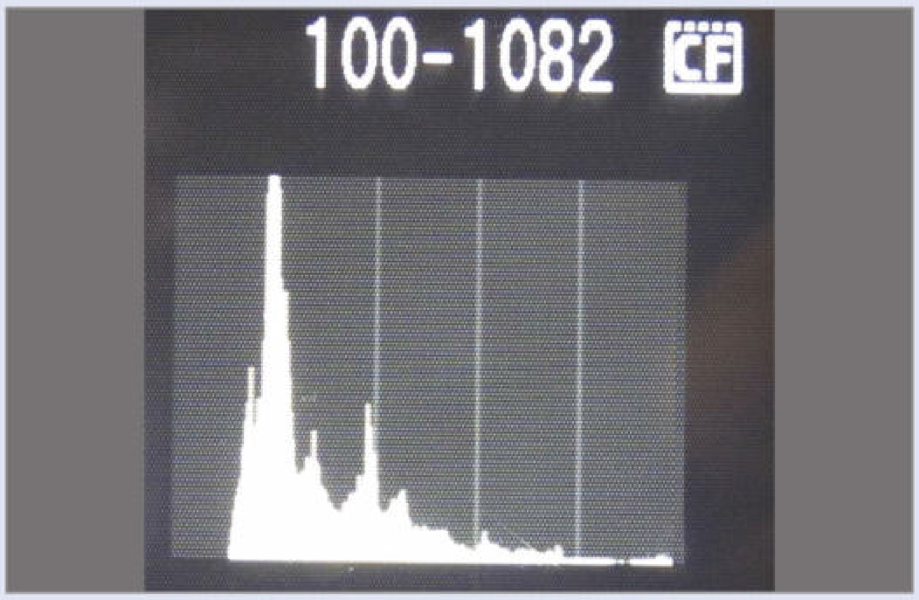
STEP 3

Monitor the weather forecast and make sure your kit is ready for quick deployment should conditions be favourable. Venus is an excellent focus object visible before the sky gets dark enough to see the Pleiades.

Next, set your camera to manual focus, pre-focus on Venus and carefully apply a piece of low-tack electrical tape around the focus ring to hold focus for several evenings.

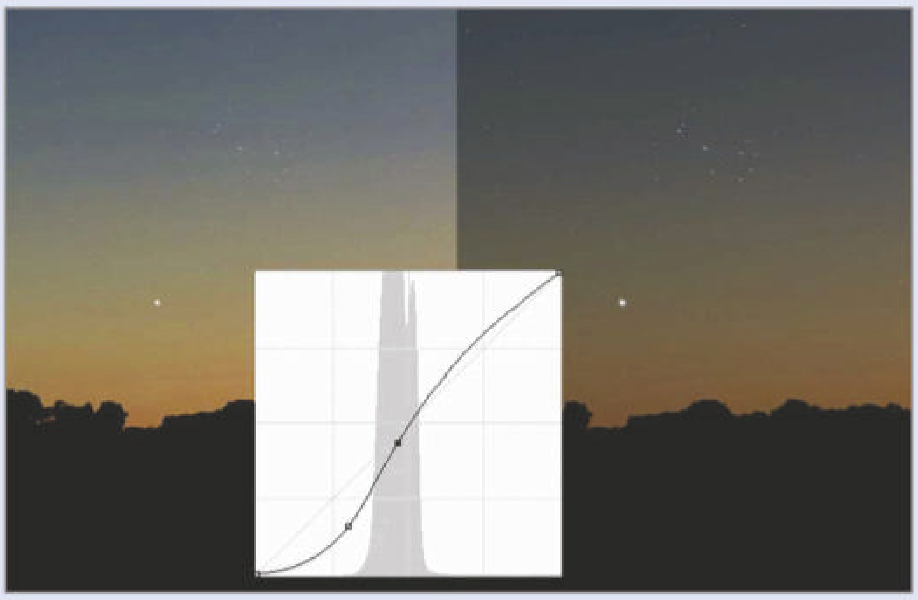
STEP 4

Set the camera's ISO low, somewhere between 200–800. If using a static tripod, open the lens then close it by a stop or two to limit distortion. Experiment with exposure to give a bright but not overexposed background sky. If your results are too dark, up the ISO slowly. Remember, this is twilight, so it will darken over time.



STEP 5

If using a polar-aligned tracking mount, use a low to medium ISO and set the f-stop number to a mid-range value, say f/11–f/16. Experiment with a multi-second exposure. Again, don't worry if the sky appears too light, just make sure it doesn't over-expose. Check the image histogram to ensure no clipping has occurred.



STEP 6

Open the final image in a photo editing program. Copy the base layer, keeping the original for backup. With the copied layer, open 'Curves'. Place an anchor where the default curve-line passed through the main histogram graph. Drag the curve to the left down so an 'S' shape is created. Tweak the S-curve as needed.

Expert processing tips to enhance your astrophotos

ASTROPHOTOGRAPHY PROCESSING

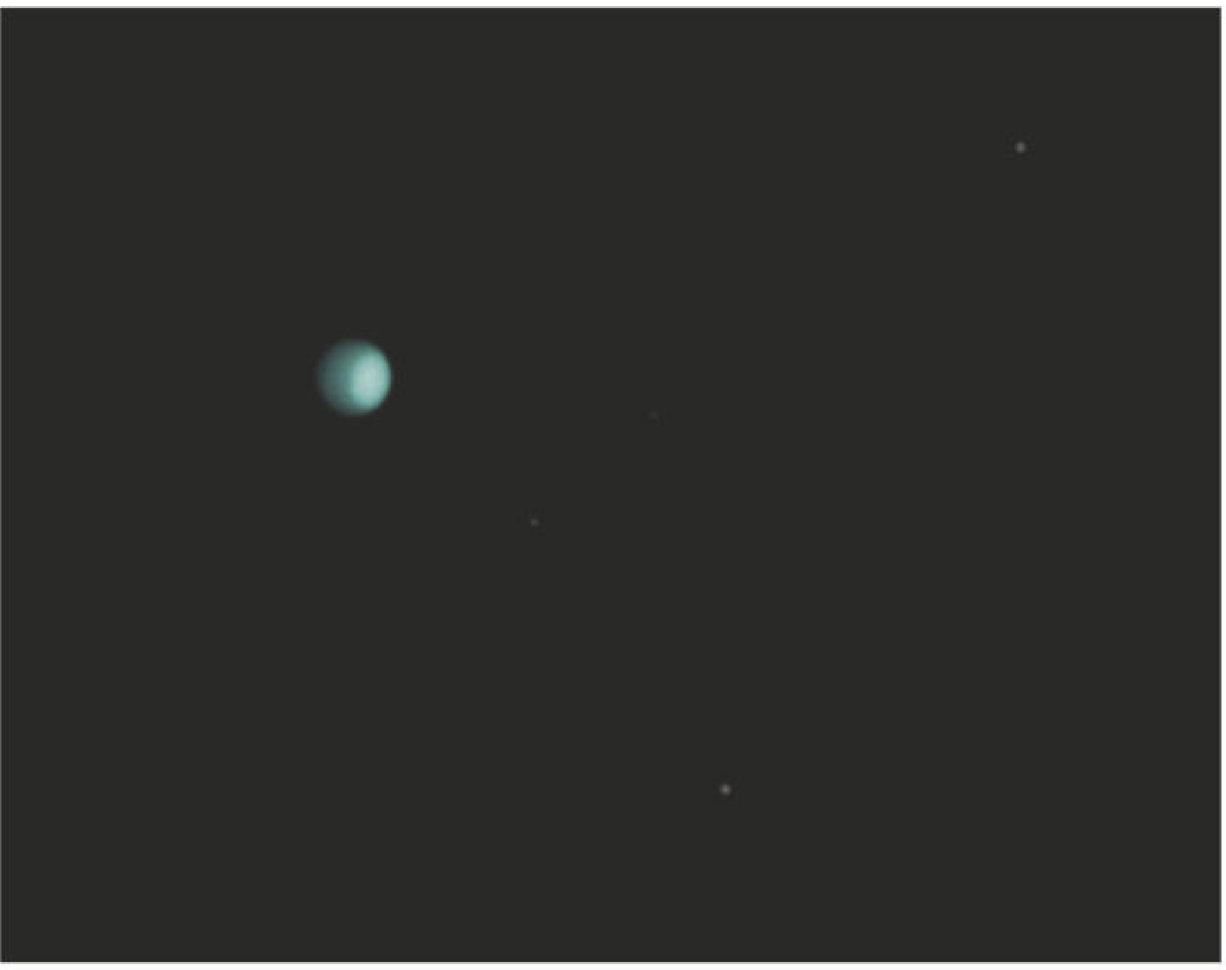
APY Masterclass

Tease detail from the ice giants

Use stacking software to bring out surface features and moons

Astronomy Photographer of the Year

Advice from a runner-up entrant in the 'Planets, Comets and Asteroids' category



▲ **Distant world: the final image of Uranus, entitled 'In the Outer Reaches'**

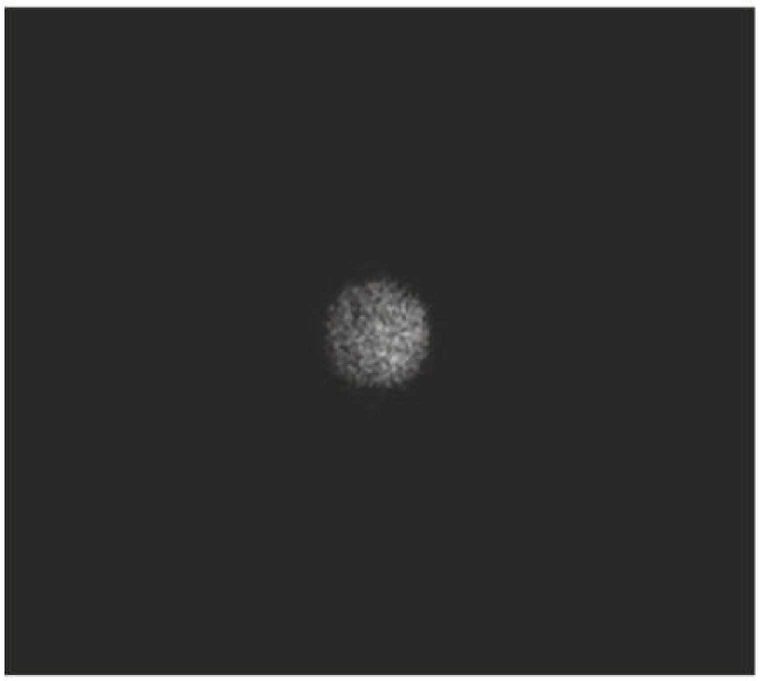
For the 'Planets, Comets and Asteroids' section of the 2020 Astronomy Photographer of the Year competition, I was fortunate to secure second place for my image, 'In the Outer Reaches' (above). The image shows the distant ice giant, Uranus, as a pale-green disc accompanied by its five brightest moons. In the shot the planet's lighter northern polar region and subtle single darker belt indicate the ice giant's extreme axial tilt.

The image was taken on a night of exceptional seeing in December 2019 from my garden in St Albans and captured using my home-built 444mm Dobsonian sitting on an equatorial tracking platform.

Trying to image the ice giants, Uranus and Neptune, is challenging due to their faintness, small size, and subtlety of surface features. Fortunately, the task has become much easier in recent years, due to the improvements in both the sensitivity and noise reduction (reducing unwanted artefacts) of CMOS-based planetary imaging cameras, which allow the use of much shorter frame exposures. Not so long ago, frame exposures of 0.5 seconds or longer would be required for Uranus, leading to high levels of smearing by atmospheric movement and resulting poor definition. With some of the new generation CMOS video cameras, scopes of 150mm aperture or larger should, in good seeing conditions, be able to easily capture the lighter polar region of the planet.

Keeping the image bright

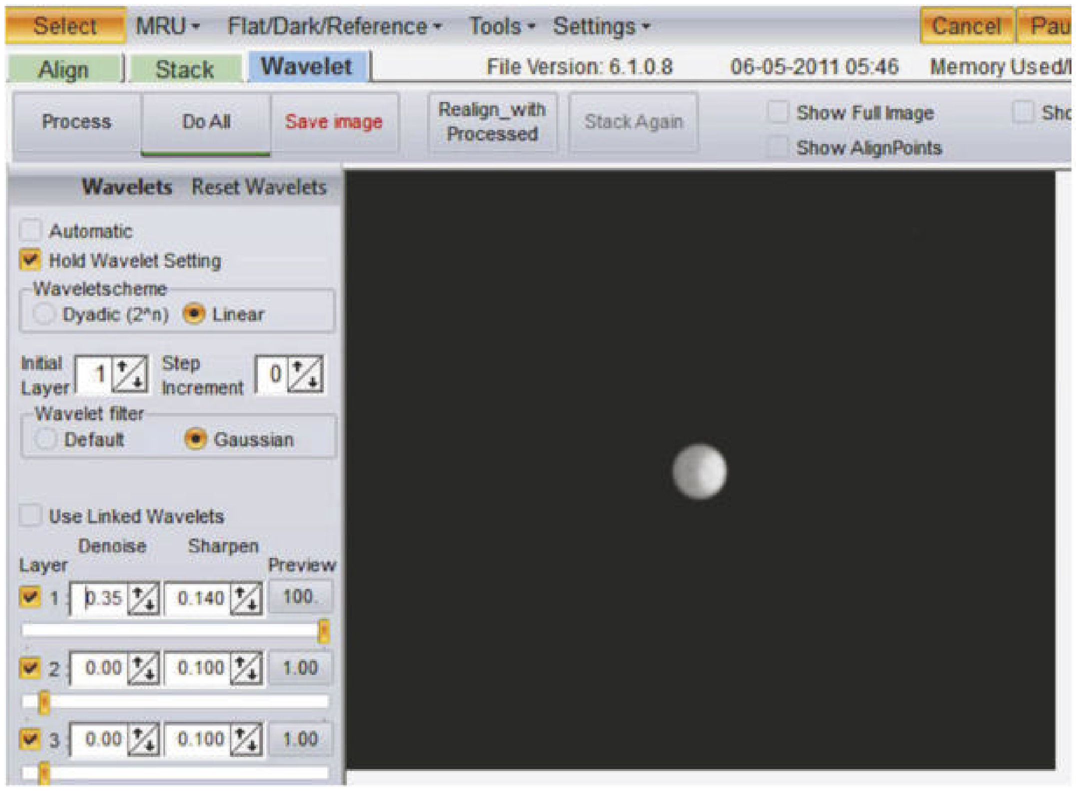
For my image that night I used a 2.7x Barlow lens giving a focal ratio of f/12.7. With my infrared-sensitive, monochrome ASI290MM camera, this gave an image scale of 0.11"/pixel. At a relatively high gain of 54dB, the camera's high sensitivity allowed me to use an exposure of just 8.6 milliseconds and still keep the image bright. Infrared imaging helps steady the



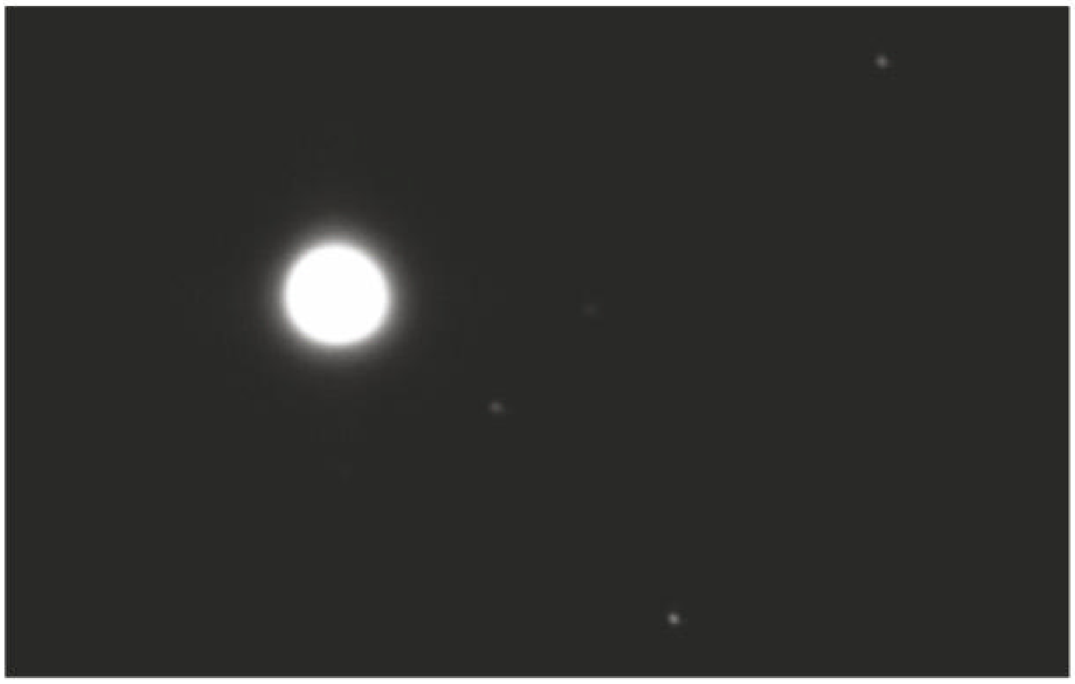
► **Stage 1: a single video frame, taken on 3 December 2019, reveals lots of noise (unwanted artefacts)**

ALL PICTURES: CHARLOTTE DANIELS

◂ **Stage 2: stacking thousands of frames in AutoStakkert! reduces noise levels and brings out the lighter polar region**



▾ **Stage 3: a screenshot showing the RegiStax 'Wavelets' settings for drawing out planetary detail**



▴ **Stage 4: a stacked and stretched image of Uranus's moons; before sharpening and combining with the image of the correctly exposed planet**

views and is essential for improving the contrast of Uranus's surface detail. I used a 610nm long-pass filter, which works well – as it passes more light than most other infrared filters operating at longer wavelengths.

With these camera settings, the individual video frames look very noisy (full of unwanted artefacts) due to the lack of photons (see Stage 1, opposite), but when you stack lots and lots of these frames in AutoStakkert! or RegiStax, the long-accumulated exposure time means that the noise levels drop (see Stage 2, left, top). For my image I stacked the best 13,500 frames in AutoStakkert!, out of a total of 90,000 frames gathered over 20 minutes.

Next, the stacked image was wavelet-processed in RegiStax 'Wavelets' to draw out the details, using just the 'Denoise' and 'Sharpen' settings in the first level (as shown in the Stage 3 screenshot, left).

To capture Uranus's fainter moons, I recorded later videos with a larger region of interest at maximum camera gain (60dB), and a longer exposure of 100 milliseconds. Next, I stacked the best 45 per cent of 2,600 frames taken over five minutes. Minimal sharpening was needed in RegiStax, but the gamma function, at 3.3, brightened the moons with respect to the dark background (see Stage 4, below, left).

The nicely exposed moons (with an overexposed Uranus) then had to be combined with the correctly exposed planet. This was easy as the camera was not rotated between imaging the two. The moons layer was used as the bottom layer of a new image in PaintShop Pro and the good planet layer pasted on top. The top planet layer was then moved until Uranus's disc exactly covered the over-exposed version in the bottom moon layer. Reducing the 'Opacity' of the top layer to 60-70% allowed me to get the alignment spot-on by being able to see both together. The reduced 'Opacity' also allowed me to see the moons in the bottom layer – that was important as the next step was to erase holes in the top layer to reveal the moon on the bottom layer. Once all were revealed the 'Opacity' was set to 100%.

Before merging the two layers the planet layer was colourised to make a more pleasing pale green. I used RGB colour balance settings of Red: –20%, Green: +14% and Blue: +14% for this. Once colourised and merged, the image was finished; a pleasing capture of one of Earth's distant neighbours, orbiting in the far regions of our Solar system.

3 QUICK TIPS

1. See the *BBC Sky at Night Magazine* article on 'How to take photos of Uranus and Jupiter' at **bit.ly/3rkGfVo**

2. Use an imaging focal ratio calculated at about 3x to 5x your pixel size in microns. For a 3.5µm pixel camera, a focal ratio of f/10 to f/18 is best.

3. Remember, the longer you gather frames for, the less the noise (unwanted artefacts) and the better the detail will be; try for at least 10-15 minutes of video capture.

Martin Lewis is a planetary imager who was runner-up in the APY 2020 'Planets, Comets and Asteroids' category with 'In the Outer Reaches'

Your best photos submitted to the magazine this month

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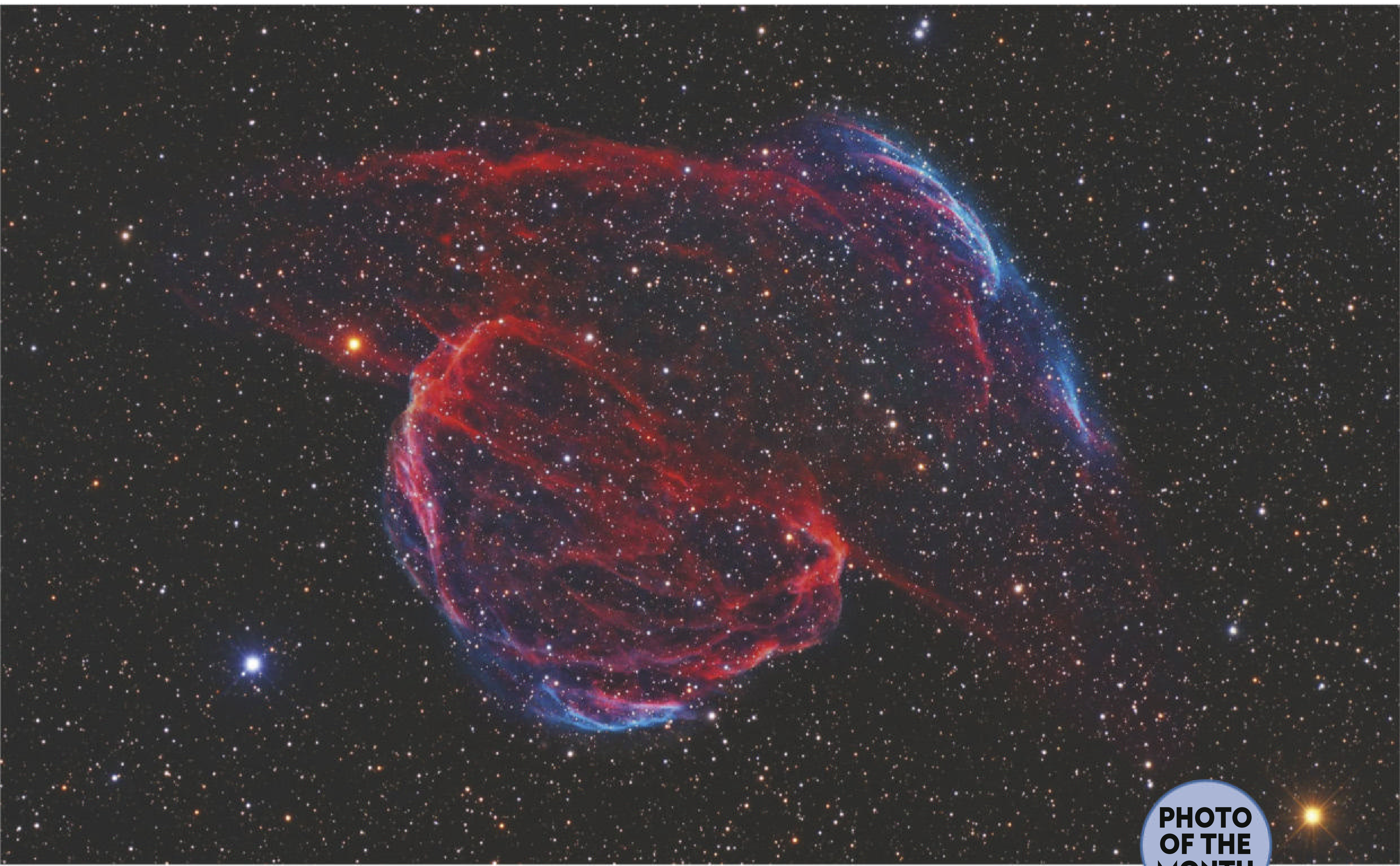


PHOTO OF THE MONTH

△ Sh2-224

Francis Bozon, Jean-Luc Gangloff, Stéphane Gueyraud, remotely via Dark Sky Alqueva, Portugal, 11 October–22 December 2020

Francis says: "Sh2-224 is a very faint supernova remnant in the constellation of Auriga, the Charioteer. It has a rather peculiar asymmetric shape, with a shell structure that has a radius of about 75 lightyears. We captured this remotely from France. The observatory is located in the Alqueva area of southern Portugal, where major efforts are being made to control light pollution."

Equipment: ZWO ASI 1600MM Pro camera, Takahashi FSQ-106ED apo refractor, Sky-Watcher AZ-EQ6 GT mount
Exposure: Ha 219x 300", OIII 179x 300", L 19x 60", R 21x 90", G 20x 60", B 23x 60"
Software: PixInsight, Photoshop

The team's top tips: "As this object is very faint, good seeing conditions and clear skies – as we had in Portugal – are absolutely essential. While a telescope with a very sensitive camera similar to ours works well, you can also use a scope with a larger focal length and a camera with a larger sensor (24mm x 36mm). It's essential to capture a large amount of data. We gathered around 33 hours in total. Using a narrowband Ha (Hydrogen-alpha) filter gives the best result for this target, as the OIII (Oxygen) afterglow on the outer edges is very faint."

◁ Mineral Moon

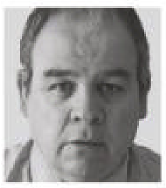
Sona Shahani Shukla, New Delhi, India, 23 February 2021

Sona says: "I'm delighted to have imaged the Moon to my liking with a manual Dobsonian. It's a bit of a challenge, but once you know your equipment well, there's no feat you can't achieve."

Equipment: ZWO ASI 178MC colour camera, 8-inch Sky-Watcher FlexTube 200P Dobsonian **Exposure:** 1,000 frames per panel, 53 panels total, 25 per cent stacked **Software:** SharpCap Pro, RegiStax, Photoshop

The Hamburger Galaxy ▷

Mark Shelton, Birmingham, 20 December 2020–21 January 2021



Mark says: "The biggest challenge was the very low altitude of the constellation the target is in, Leo, the Lion. I was fighting very poor seeing but it came out well despite this and my heavily light-polluted sky."

Equipment: ZWO ASI 6200MM camera, Celestron C14 SCT, Paramount MX+ mount **Exposure:** 230x 5' **Software:** PixInsight, Photoshop

◁ The Seagull Nebula & Thor's Helmet

Prabhu, Mleiha, United Arab Emirates, 16 and 17 January 2021

Prabhu says: "This wide-field image covers an area about seven times as wide as the full Moon and three times as high, straddling the border between the constellations of Monoceros, the Unicorn and Canis Major, the Greater Dog."

Equipment: ZWO ASI 1600mm Pro camera, Samyang 135mm lens, Sky-Watcher AZ-EQ6 mount **Exposure:** Ha 32x 5', OIII 23x 5', SII 30x 5' **Software:** PixInsight, StarNet

△ Milky Way over the Sky Train

Todor Tilev, County Offaly, Ireland, 12 May 2019

Todor says: "I noticed the Milky Way over the Sky Train sculpture in Lough Boora Discovery Park, and went inside to set up the torch to get this shot."

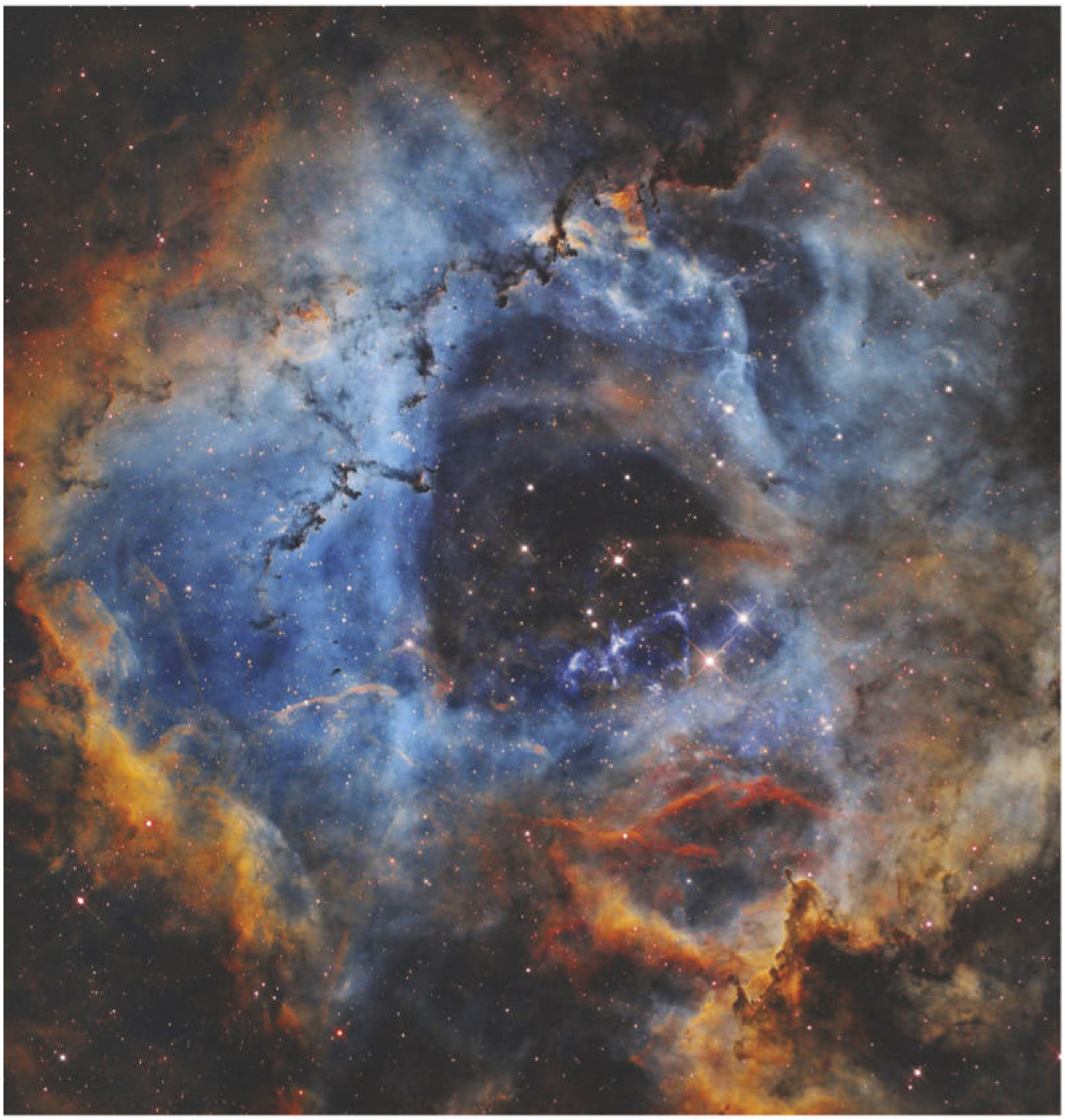
Equipment: Fujifilm X-T10 camera, Samyang 12mm lens **Exposure:** ISO 1600, 30" **Software:** Lightroom

The Rosette Nebula ▷

Shawn Nielsen, remotely via El Sauce Observatory, Chile, 23 February 2021

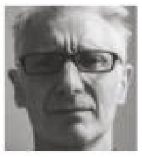
Shawn says: "There's a difference between my light-polluted skies and these pristine ones, with a better signal to noise ratio that allows more details to be captured."

Equipment: FLI PL 16803 camera, ASA 500N reflector, ASA DDM85 mount **Exposure:** 2h total **Software:** PixInsight



◁ M15

Alex Dean, Nottingham, December 2020 – February 2021

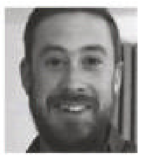


Alex says: "This is one of many final iterations where I've used the full colour (narrowband filter) range of the Hubble Palette."

Equipment: Atik 460EX CCD camera, William Optics FLT 132 apo refractor, Celestron CGEM mount **Exposure:** 5', 15h total **Software:** SGPro, PHD2, PixInsight, Photoshop

△ Mars visits the Pleiades

Dan Fleetwood, Rugby, Warwickshire, 27 February 2021



Dan says: "With a poor forecast due for the closest approach, I took advantage of the clear skies a few days earlier to capture this celestial meeting while I had the chance."

Equipment: Canon EOS 250D DSLR, Samyang 135mm lens, Sky-Watcher Star Adventurer **Exposure:** ISO 400, 90x 60" **Software:** Lightroom, DeepSkyStacker, Photoshop

◁ Andromeda Galaxy

Lloyd Mainwaring, Barry, 9 October 2020

Lloyd says: "As a *BBC Sky at Night Magazine* subscriber and podcast listener, I felt maybe it was time for me to send in one of my own images. I've been working hard over the last few years to refine my techniques and feel that finally I have an image worthy of sharing."

Equipment: Canon EOS 600D DSLR camera, William Optics GT81 apo refractor, Sky-Watcher HEQ5 mount **Exposure:** ISO 800, 80x 180" **Software:** Photoshop

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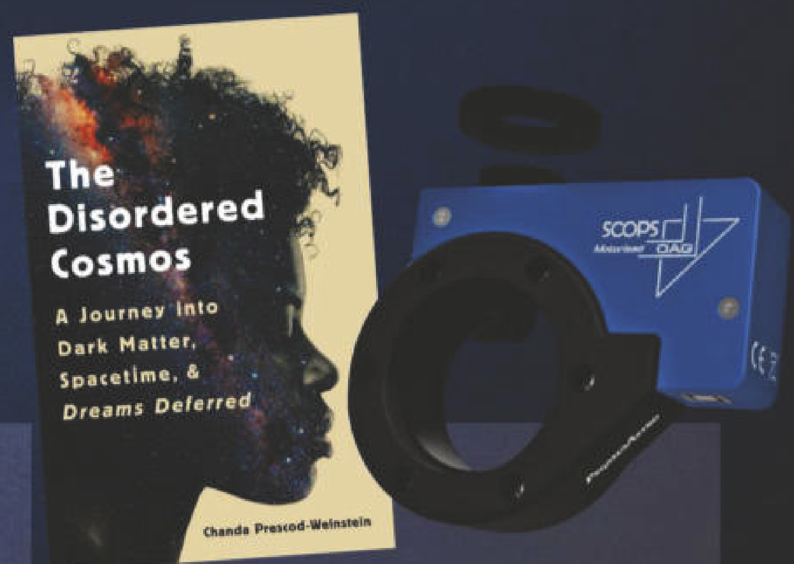
86
More than meets the eye? We discover how well the RVO Horizon 60ED Doublet refractor stacks up for astrophotography and observing



HOW WE RATE

Each product we review is rated for performance in five categories. Here's what the ratings mean:

★★★★★ Outstanding ★★★★★ Very good
★★★★★ Good ★★★★★ Average ★★★★★ Poor/avoid

PLUS: Books on being a black woman in the field of physics and Yuri Gagarin, and a look at essential astronomy gear

@THESHED/PHOTOSTUDIO

Our experts review the latest kit

FIRST LIGHT

RVO Horizon 60ED Doublet refractor (full imaging package)

A highly portable telescope that works well for imaging and visual observing

WORDS: TIM JARDINE

VITAL STATS

- **Price** £695
- **Optics** FPL-53 Doublet
- **Aperture** 60mm
- **Focal length** 360mm, f/6
- **Focuser** 2-inch rack and pinion with camera angle adjuster
- **Extras** Dovetail bars, tube clamp, guidescope
- **Weight** 1.78kg
- **Supplier** Rother Valley Optics
- **Tel** 01909 774521
- **www.** rothervalleyoptics.co.uk

The new Horizon 60ED imaging refractor from Rother Valley Optics is a lightweight, portable telescope designed for grab and go astronomy. The full imaging package we received for review includes a guidescope and a field flattener for astrophotography; although the telescope is also available on its own without accessories for a price of £499. The portability of the Horizon imaging package is particularly impressive; supplied in a sturdy case that contains the whole assembly, the only extras required for an astrophotography trip would be a DSLR camera and a suitable mount. The complete setup, including a DSLR, weighs less than 3kg, so it could be easily accommodated by most star-tracking mounts.

Setting up the Horizon 60ED imaging refractor for an imaging session is quick and simple, and first-time users will appreciate the easy to follow, three-step pictorial guide, which explains how to remove the visual back from the telescope and replace it with the field flattener. A standard 48mm T-ring screws on to the back of the field flattener, and the DSLR camera attaches onto that, which gives optimal spacing for a flat image field with no additional spacers or measuring required.

The telescope features a 60mm objective lens, and a focal length of just 360mm, which offers a wide-field image scale at a respectable f/6 focal ratio. Our full-frame DSLR camera was able to capture the three stars in Orion's Belt right down to his Sword, including the impressive Orion Nebula, M42. At this image scale, guiding the telescope over typically short DSLR exposures might not strictly be necessary on a mount with good polar alignment, but the supplied 32mm guidescope is a useful standby, which can be adjusted easily to match the imaging area, or perhaps to track on a comet while taking photos. Guide cameras with 1.25-inch nosepieces slide into the guidescope and can be adjusted back and forth to achieve focus. Alternatively, an M42 x 0.75mm male thread on the guidescope's rear allows you to attach other cameras.

Ready for action

With everything set up and ready to go in just a few minutes, we turned our attention to capturing some images. Focusing our DSLR was very straightforward too with the dual-speed option, and although the ►

ALL PICTURES: @THESHED/PHOTOSTUDIO

Colour correcting lens

The photographs, and indeed the views, provided by any telescope are only as good as the optical system allows. With refractors like the Horizon 60ED the two main considerations for optical quality are the flatness of the image – or how well the curved lens produces focused, round stars in the corners – and colour correction. As light enters the telescope through the lens, its various wavelengths behave slightly differently and the point of focus alters for each wavelength. The lens arrangement in the Horizon 60ED is an FPL-53 doublet and this very low-dispersion glass lens system has been figured to provide excellent colour correction. This was demonstrated nicely while we were imaging the Orion area; the bright blue star Alnitak (Zeta (ζ) Orionis) in Orion's Belt has a reputation for revealing any weaknesses in optical designs, but we found no issues.

To confirm these results, we spent some time observing and imaging the bright edge of a waxing Moon and were pleased to see that no false colour artefacts or colour fringing were visible.

SCALE

Dew shield and internal baffles

A retractable dew shield extends 50mm beyond the objective lens, protecting it from stray light and moisture while maintaining the compact profile of the Horizon 60ED. The inside of the tube features a baffled section to further reduce unwanted internal reflections. In addition, the aluminium end cap is etched with the RVO logo.

Field flattener

The dedicated field flattener screws directly onto the focuser drawtube, and the camera T-ring screws onto the back of it, helping to eliminate unwanted flexure. This extra lens adjusts for the effects of residual coma in the objective, ensuring stars in the corners of the image are tight and round.

Guidescope

With its own dovetail and tube rings that match the main telescope, this handy little 32mm guidescope is quickly attached to the Horizon 60ED, and with the help of an eyepiece it's easily aligned to the same axis. We found plenty of suitable guide stars were available through the guidescope.

Focuser

The Horizon focuser is a rack and pinion dual-speed design, which is compatible with auto-focusers. In addition to the handy camera angle adjuster (CAA), or rotator, there is a useful tension adjuster on top of the focuser to accommodate and adjust the focuser for a range of cameras and visual accessories.

Carry case

The stylish aluminium carry case will neatly house the telescope, guidescope, dovetail bars and field flattener with room for more, and protect the scope during storage and travelling. It is lightweight and lockable, measuring just 41 x 23.5 x 18cm, well within the limits for airline cabin baggage.

◂ The Pleiades, M45 – taken using a Canon 6D Mk II DSLR, using a 28-minute integration of 60" exposures

▴ An image of Orion's Belt and Sword, taken with the same setup, using a 16-minute integration of 60" exposures

▸ focus lock knob was a little awkward to access with cold fingers, once locked the focus held well in stable temperatures.

With the comparatively wide view available to the camera, we wanted to frame each shot for best effect, and this was easily accomplished with the built-in rotator. This sits in front of the field flattener, a single thumbscrew allowing the camera to rotate 360°. Once set, we started taking images within the constellation of Orion, the Hunter to assess the performance of the field flattener. This proved to be remarkably good, especially given our full-frame camera, with just a little distortion to star shapes in the corners of the image; indeed, the reassurance that the camera and scope were nicely matched allowed us to get on with astrophotography, no fiddling about required – exactly what we look for in a portable setup.

Removing the flattener and reattaching the visual back allowed us to use our 2-inch diagonal and eyepieces for a visual observing session, as a bright Moon dominated the sky. Our 13mm, 100° apparent-field-of-view eyepiece offered us around 28x magnification; ideal for exploring large clusters like the Pleiades, M45, where we noted a nice contrast and good star shapes across most of the view. Despite the bright Moon we were able to pick out a good amount of nebulosity around the Orion Nebula, M42, and moving down through 10mm and 5mm eyepieces the Trapezium area was clear and sharp. Although primarily aimed at the astrophotography community, we found the Horizon 60ED offered pleasing, encompassing views, allowing the viewing of familiar targets in their wider context.

Overall, we were pleased to discover that the Horizon 60ED refractor is a well-priced, very capable astrophotography telescope – in an extremely portable package – with the added bonus of pleasant visual observing as an option.

VERDICT

Build & design	★★★★½
Ease of use	★★★★½
Features	★★★★★
Imaging quality	★★★★½
Optics	★★★★½
OVERALL	★★★★½

KIT TO ADD

1. Rother Valley Optics M48 T mount

2. ZWO ASI120MM Mini Monochrome CMOS USB 2.0 camera

3. iOptron SkyGuider Pro camera mount

Our experts review the latest kit

FIRST LIGHT

Opticron Oregon WA 10x50 binoculars

An affordable, lightweight pair of binoculars that will inspire newcomers to the hobby

WORDS: STEVE TONKIN

VITAL STATS

- **Price** £69
- **Optics** Fully multi-coated
- **Magnification** 10x
- **Aperture** 50mm
- **Prisms** Porro, BAK4
- **Angular field of view** 6.5°
- **Focusing** Centre focus, eye relief: 16mm
- **Interpupillary distance** 58–73 mm
- **Weight** 885g
- **Supplier** Opticron
- **Tel** +44 (0)1582 726522
- **http://** opticron.co.uk

Many experienced observers consider 10x50 binoculars to be the ideal size for those who are dipping their toes into binocular astronomy. Not only do they have enough aperture to give bright images, combined with enough magnification to reveal star clusters and galaxies, but their weight (885g) is light enough for you to hold them easily by hand.

When you first take the Opticron Oregon WA 10x50 binoculars out of the lined nylon case, you'll find that they come with a 25cm-wide neck strap, tethered lens caps for the objective lenses, a rain guard to protect the eyepieces, a microfibre cleaning cloth and an instruction card. The aluminium alloy body is mostly covered by a thin rubber armour that gives a secure grip with either bare or gloved hands, even if it's damp with dew. The wide centre focus wheel, right eyepiece dioptre and central hinge have appropriate stiffness and smoothness. At the minimum interpupillary distance (the distance between the pupils of your eyes) of 58mm, there is 16mm between the rubber eye cups, enough to avoid them squeezing the bridge of your nose. We noticed that the prisms are clipped in place and not held in a cage, which potentially makes them susceptible to becoming dislodged – but the five-year guarantee, unusual for an entry-level pair of binoculars, inspires confidence that the manufacturer has secured the prisms effectively.

Controlling light

We held the binoculars up to the light and examined the exit pupils (the light emerging from the eyepieces), noting that these are perfectly round with no black or grey segments. This indicates that the prisms are appropriately sized and confirms the use of high-index glass. When you shine a light into the objective lens, the muted reflections are consistent with the fully multi-coated specification, and this combined with the ribs inside the objective tubes suggests that stray light should be well-controlled. Indeed, we could not find any spurious reflections when the gibbous Moon was inside, or just outside, the field of view.

The Moon also offers a test of chromatic aberration (an effect usually seen as unwanted coloured rings around brighter objects); although there is a slight ▸

ALL PICTURES: @THESHED/PHOTOSTUDIO

Wide and bright field of view

Aperture is king in astronomy, but it is often the case that modern budget binoculars have their apertures stopped down internally – sometimes by 20 per cent or more – in an attempt to sharpen the image at the cost of some loss of brightness. We were delighted to find, however, that this is minimal when it comes to the Opticron Oregon WA 10x50s: we measured the effective aperture as 47mm. Coupled with this, the anti-reflective multi-coatings ensure that the binoculars pass a maximum amount of light to your eyes. Consequently, the images were pleasingly bright and had good colour rendition.

The 6.5° field of view is at the wide end of the range for astronomical 10x50 binoculars and, although the image does get soft towards the edges, the sense you get is of a field of view that you have space to look around in. This is particularly helpful if you are star-hopping or scanning in search of your target: there is more chance that your next 'star stop' will be conveniently visible in a wider field of view.

Tethered lens caps

Caps are essential to protect your lenses from degrading dust and other airborne debris, and they are unlikely to get lost if you can keep them tethered to the binoculars. For your convenience, the objective caps are removable if you would prefer to not have them tethered.

Smoothly operating focusing

Both your centre-focus wheel and your right eyepiece dioptre adjuster need to be sufficiently resistant to prevent accidental refocusing, but smooth enough to enable you to focus very precisely. The backlash-free adjustments to both focusing devices met these criteria and are designed to be operable with thickly gloved hands.

Good right eyepiece dioptre range

Most of us do not have perfect eyesight and the optical defects we do have will differ between our eyes; this is why centre-focus binoculars have a right eyepiece focus adjustment. This one has a range of ±3.5 dioptres, so it can compensate for quite severe disparity between your eyes.

FIRST LIGHT

Tripod-mountable

Although these binoculars can very easily be hand-held, all binoculars will show you more if you steady them by mounting them on a tripod or, often more conveniently for high elevation targets, a monopod. Under a cap on the hinge, you'll find a threaded bush that accepts the necessary adaptor.

Fold-down rubber eye cups

The rubber eye cups are pliable enough for comfort and they fold down to enable you to see the full field of view if you need to observe with spectacles. They incorporate a rubber flange that covers the eye-lens surround so that your spectacle lenses won't accidentally rub against the eye lens.

▸ amount of false colour at the centre of the field of view, nowhere does this become overly intrusive. Stars in the central two thirds are very sharp, and we were able to keep the components of the double star Delta (δ) Cephei (40 arcseconds separation) split to about 80 per cent out, as well as distinguish the colours of the two stars. Turning our attention to other winter binocular targets, we explored the curves and groups of stars in Collinder 70 (the region around Orion's Belt), which were a delight. The Orion Nebula itself began to show structure, with the 'Fish's Mouth' inlet being prominent, while the stars of the Meissa Cluster revealed their various colours. The Leaping Minnow asterism and Messier clusters in the constellation of Auriga, the Charioteer were all distinct, while the Beehive Cluster, M44 in Cancer, the Crab clearly showed the mass differentiation that pushed the fainter stars further from the middle. Once Bode's Nebula, M81 and the Cigar Galaxy, M82 achieved a reasonable altitude, they were obvious with direct vision. We also found it easy to identify asteroid Vesta, which was almost at its best for the year and is the brightest of the asteroids.

Although these binoculars have a satisfyingly sturdy feel to them, this does not come at the expense of decent ergonomics. You will find that they are well-balanced, and light enough for you to hold for extended periods. While they do have some shortcomings (as do all but the most expensive premium binoculars), there is nothing severe or obtrusive enough to make them difficult to use or to markedly degrade the image. In fact, you probably wouldn't even notice the few niggles we found unless you were actively looking for them. It's as if someone has been paying attention to what binocular reviewers have, for many years, been asking for in an entry-level pair of 10x50 astronomical binoculars and, at last, given it to us.

Whether you're just starting out in this wonderful hobby, or are an experienced observer who wants some inexpensive binoculars for quick wide-angle vistas and other casual use, the Opticron Oregon WA 10x50s are definitely worth a look.

VERDICT

Build & design	★★★★½
Ease of use	★★★★½
Features	★★★★½
Field of view	★★★★
Optics	★★★★
OVERALL	★★★★½

KIT TO ADD

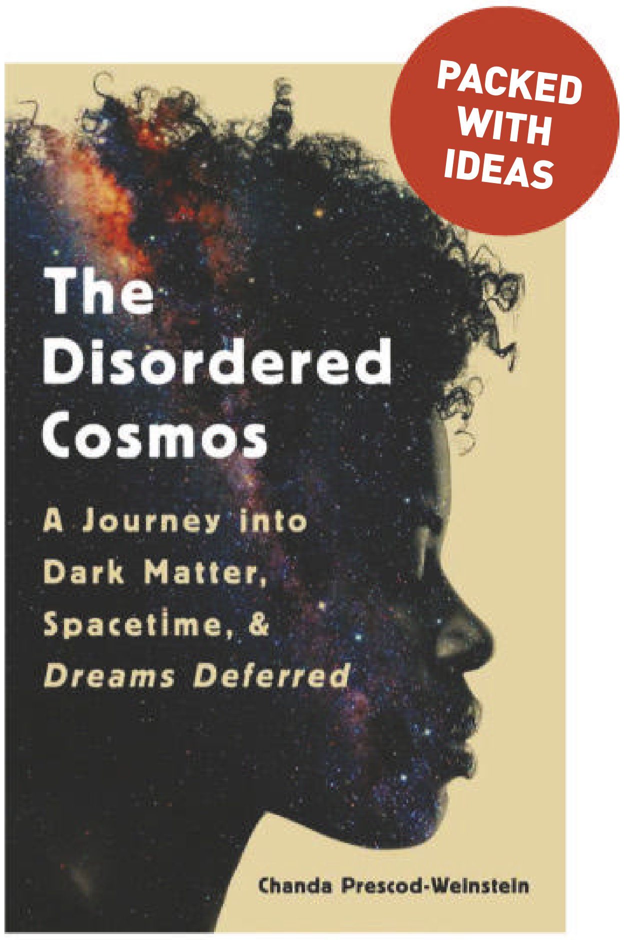
1. Opticron 31004 tripod mount

2. Velbon Sherpa monopod

3. Opticron ball and socket panhead

ALL PICTURES: @THESHED/PHOTOSTUDIO

BOOKS



The Disordered Cosmos

Chanda Prescod-Weinstein
Hachette
£20 ● HB

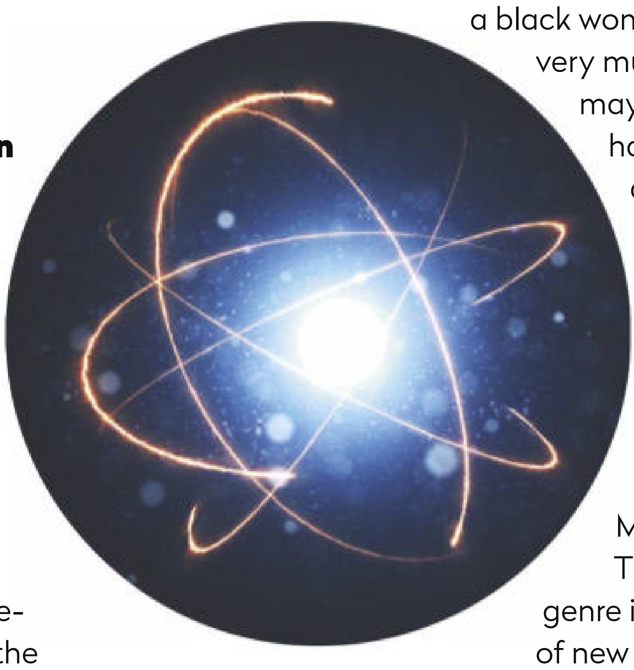
Dr Chanda Prescod-Weinstein's debut book is two things: a journey into the world of cosmology and particle physics, and a refreshingly eye-opening insight into the too-often exclusionary arena that is science.

The book's main premise is that physics doesn't just affect us all as a society, but it taps into our natural desire to learn and understand; and yet one group for many centuries, and even to this day, has deemed itself worthy to tap into that knowledge above others. If physics is for everyone, then where is the justification to gate-keep?

There are parts of *The Disordered Cosmos* that read a bit like a popular science book, but the perspective is refreshingly different. It's not often that physics is presented from the point of view of a black woman: in fact it's so unusual that it's a sad rarity.

Do not pick up this book thinking it will be just another title on particle physics or dark matter. It does explore those areas in an engaging and accessible way, from the Standard Model of Particle Physics – its origins and where it currently stands – to the latest theories on dark matter, but Dr Prescod-Weinstein's experiences of navigating her way within the field of physics as a black woman – punctuated with many examples of racism and sexism – are interwoven throughout.

What I enjoyed most about this book was its raw honesty. I found its vibrant, bold and non-traditional take on the field of physics to be refreshing, saddening and frustrating to read at times – especially as a black woman myself – but very much needed. You may wonder what race has to do with physics, and the answer is everything, including why our skins are the colours they are (explained in captivating detail in the 'Physics and Melanin' chapter).


▲ *The Disorded Cosmos* is far more than a traditional look at particle physics

COKADA/ISTOCK/GETTY IMAGES

The popular science genre is in desperate need of new voices that aren't the typical standard we are unwittingly used to, and as a starting point I cannot recommend this book enough, especially for people of colour wanting to enter a field that, because of their gender or race, may seem like a lonely place. ★★★★★

***Melissa Brobby** is a science communicator and social media lead at the Institute of Physics*

Interview with the author
Chanda Prescod-Weinstein

How much do we know about the Universe?

In theory, we know what the Universe is made of, that all matter-energy content is 'normal' matter, dark matter or dark energy. But 'normal' is only about four per cent of the total matter-energy content, and that includes us. Humans are not just abnormal because there is only one Earth, it's because most of what we see is a tiny percentage of the Universe's matter-energy content. The rest is dark matter and dark energy.

What do we know about the Big Bang?

People think of the Big Bang as like an explosion, but if it really was a thing, it's a moment in time that happens everywhere. When the Universe was less than a second old, space-time expanded exponentially. Perhaps lots of bubbles of space-time popped off at the same time, so we're in one bubble and there are others that have been forming eternally into the past and the future. Maybe there wasn't a beginning, but there are many starts to different parts: something that's always been happening and always will be.

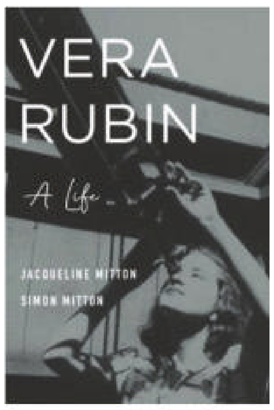
Are the Universe's laws universal?

Data is fairly consistent that laws don't change, but our understanding may be limited. Maybe we don't have gravity worked out, but everything is self-consistent. We have a tapestry of equations that work, whether we're looking through a scope or an electron microscope. The one thing all human societies have had in common is that they've looked at the sky and told stories about it; it's part of who we are.

***Dr Chanda Prescod-Weinstein** is a theoretical physicist and an assistant professor at the University of New Hampshire*

Vera Rubin: A Life

Jacqueline Mitton, Simon Mitton
Harvard University Press
£23.95 ● HB



Until Vera Rubin, no one was really sure about dark matter. It was a theory, but without her work, few were truly convinced by it. That all changed when Vera Rubin's work on galaxies showed dark matter was needed to explain what she was observing.

Despite her importance, no other biography exists of Vera Rubin – though curiously, a children's picture book about her was published in March this year.

Rubin is a fascinating character, not only for her great scientific achievements but for the example she set in how to tackle gender inequality in science. There are some lovely excerpts of letters in the book, showing her using logic and her position to speak up for equality in a way that is both polite and direct.

This book is hugely detailed, both in its use of primary sources and in the explanations of the science involved. However, while the authors clearly respect Rubin's work and her role as an astronomer, I didn't always feel I got a sense of how she related to other people. The astronomer Margaret Burbidge, for example, is mentioned as a role model and appears throughout the story, but what their friendship or work relationship was like never comes through. There is so much information packed in the book, it sometimes gets in the way of the human story that is necessary in a biography.

But no matter: this is a great introduction to an important woman and her work. ★★★★☆

***Emily Winterburn** is a science historian and author of The Quiet Revolution of Caroline Herschel*

Planets

Dr Emily Drabek-Maunder
National Maritime Museum
£9.99 ● PB

It may surprise you to know that the hottest planet in our Solar System is not the one closest to the Sun – and the coldest is not the one that's furthest away! This is a lesson to bear in mind as we search for other habitable worlds. In *Planets*, Dr Emily Drabek-Maunder takes us on a whistle-stop tour of our Solar System, outlines what we know about how the planets form, introduces us to the search for planets around other stars and takes a brief look at the prospect of life beyond planet Earth.

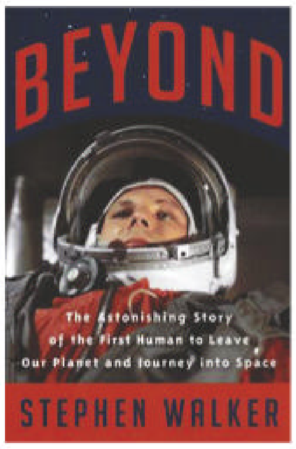
The discussion of our planetary neighbours largely focuses on their size, atmosphere, orbital period and, as noted above, temperature. Characteristics that we find are key to the search for exoplanets and life are detailed in the chapters that follow. In only 110 pages, the book was never going to be able to provide a comprehensive overview of all our knowledge acquired to date, but then that was never its aim: as with other titles in the new Royal Observatory Illuminates series, *Planets* provides a brief, accessible introduction to the subject, and it does so very nicely. It is well written, with an easy to read style that reminds me of a Royal Institute Christmas lecture. Figures, photographic plates and footnotes all serve to support the text throughout the book, and a very helpful glossary is provided at the end.

As a concise introduction, *Planets* manages to cover an impressive amount and will undoubtedly leave the reader keen to learn more. ★★★★★

***Dr Penny Wozniakiewicz** is a lecturer in space science at the University of Kent*

Beyond

Stephen Walker
William Collins
£20 ● HB



Hollywood screenwriters often include a 'save the cat' scene early on, to give audiences empathy with their hero. Stephen Walker's history of Yuri Gagarin's spaceflight starts with a 'save the dogs' example. Canine cosmonauts on a 1960 Vostok test flight touch down safely in Siberia, but the KGB had insisted on including a self-destruct device in case of a landing in the West. It activates anyway, and two rescuers draw lots for who disarms the bomb – both wish to try. This sets the scene of what follows: brave people trying to accomplish great things despite the dysfunctional society they inhabit. The KGB had to be talked out of putting self-destruct devices on board human Vostoks too.

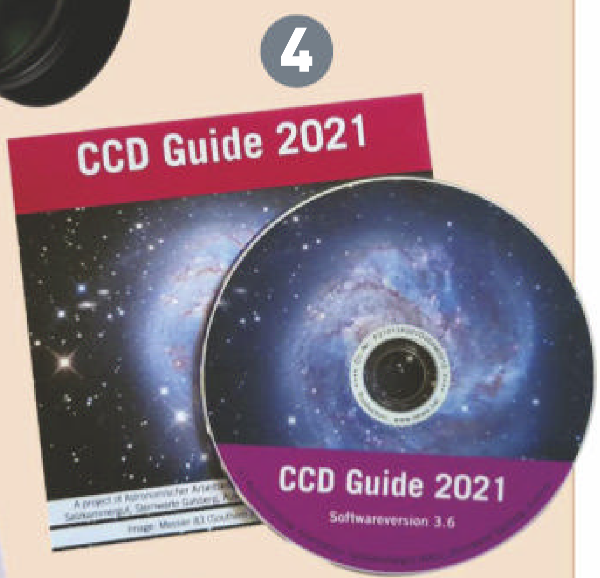
This is not a narrow biography of the straightforwardly heroic Gagarin, but tells the wider story behind his 106-minute flight, extending to his fellow cosmonauts as well as their American rivals. On average cosmonauts were a good 10 years younger than their astronaut equivalents, with much less flight experience. The Soviet emphasis was on fitness, not flying ability; these first cosmonauts were more cargo than crew. The author joins the dots to the grim tally of test animals flown (and often sacrificed) on both sides of the Iron Curtain, preparing the way for human explorers.

A documentary maker, Walker returned to primary sources and living witnesses wherever possible. The result is a gripping story, rich in novelistic detail. For example, on the night before Gagarin's flight a strain gauge was hidden under his bed; if he had tossed and turned in his sleep, he would have been replaced with backup Gherman Titov. And the famous CCCP adorning Gagarin's helmet? It was painted on the morning of the launch, in case Soviet peasants mistook him for a US spy. Highly recommended. ★★★★★

***Sean Blair** writes for the European Space Agency website*

Ezzy Pearson rounds up the latest astronomical accessories

GEAR



1 Pegasus Scops motorised off-axis guider

Price £495 • **Supplier** Widescreen-Centre
www.widescreen-centre.co.uk

ADVANCED Stay on target while taking astrophotos with this off-axis guider (OAG). The OAG sees the same view as your main scope, increasing precision. The Scops OAG is motorised to stay focused and the supplied software can make filter profiles to ensure the view stays crisp.

2 Forclaz Merino wool tube scarf

Price £9.99 • **Supplier** Decathalon
www.decathlon.co.uk

Made with Merino wool, this tube scarf can be worn in a variety of ways to keep you warm while observing; wear it around your neck, over your nose or twisted up as a hat. Available in green, blue, red and white.

3 Explore Scientific 10x60 finder and guidescope

Price £195 • **Supplier** Harrison Telescopes
Tel 01322 403407 • **www.harrisontelescopes.co.uk**

This versatile scope can either be used with the supplied removable eyepiece and illuminated crosshairs as a finderscope, paired with a camera for guiding, or used with 1.25-inch eyepieces (5mm to 26mm focal length) to act as a mini telescope.

4 CCD guide 2021

Price €29 • **Supplier** Astro Systeme Austria
www.ccdguide.com

The images and software on this DVD guide will inspire and help you plan out your next astro-imaging project. This new release has over 5,300 images and the software has been updated for more functionality.

5 NASA backpack

Price £19.99 • **Supplier** Thumbs Up
www.thumbsup.com

The simple design of this backpack features the NASA logo on a white background, accented with gold zips and a blue, compartmentalised interior, meaning you can stay stylish and organised while on the go.

6 Sky-Watcher stainless steel tripod

Price £139 • **Supplier** Telescopes Direct
Tel 020 3733 2177 • **www.telescopes-direct.com**

With 1.75-inch-diameter stainless steel legs, this tripod is a great upgrade if your setup is a bit flimsy. The legs extend from 83.5cm to 115cm and come with a ⅜-inch tripod thread to attach your mount.

BBC Sky at Night MAGAZINE

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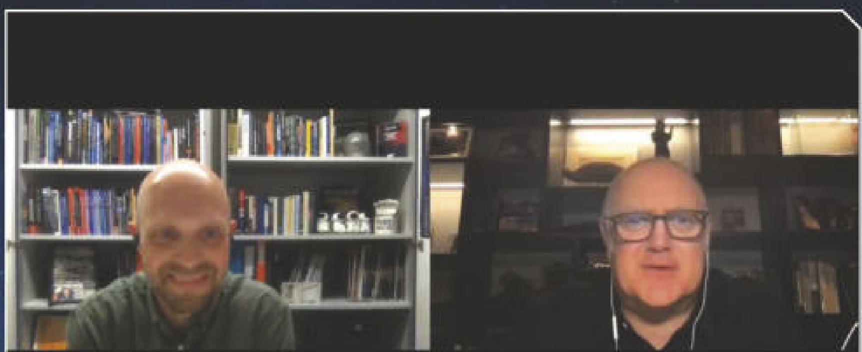

My Lockdown Project: Learning Astrophotography, with Dara Ó Briain, 25 March 2021

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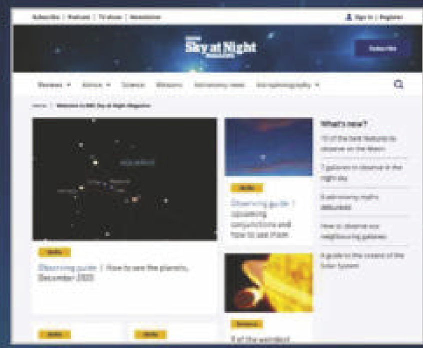

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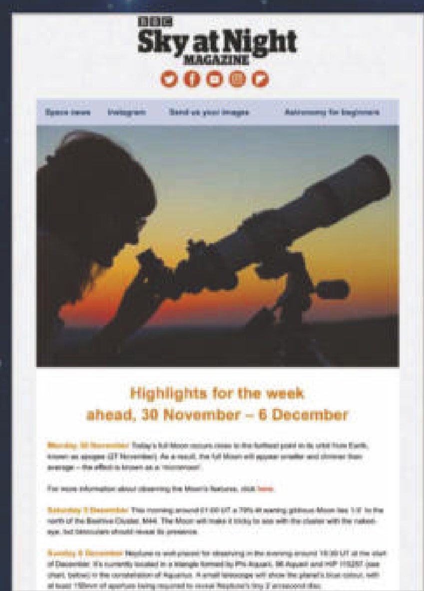

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Shaoni Bhattacharya interviews Anna Frebel

Q&A WITH A STELLAR ARCHAEOLOGIST

Battle of the galaxies: could faraway stars in an ancient dwarf galaxy upturn our understanding of galaxy evolution?

What is a dwarf galaxy?
Dwarf galaxies are a few thousand stars with a dark matter halo around them. We know of star clusters in the Milky Way – they have up to a million stars, but they don't have a dark matter halo pushing the stars together, they just hold each other. Dark matter acts like normal matter, which means we can measure its gravity. When you have a galaxy, its stars literally feel this gravity. Based on simple laws of physics we can deduce that this dark matter halo is there.

What study was published in *Nature Astronomy*?
We were looking at the faint dwarf galaxy Tucana II. As we often do – we looked for something and then found something different. I've studied many of the 30 small galaxies orbiting the Milky Way trying to work out the chemical composition of their stars so that we can learn what has happened over billions of years. The stars tell us that story. Usually I use spectroscopy to turn the starlight into rainbows to study, but because these small galaxies are far away, you don't get enough photons with your telescope. That's a big problem because it means we can only study the brightest stars, and characterising an entire galaxy with only one star is far from ideal.

So, along with my PhD student Anirudh Chiti, we developed a new technique to get information on composition based on specialised images rather than spectra. The motivation was to move beyond the one, two, three stars per galaxy and turn it into 10, 20 and 30. We used the SkyMapper Telescope to do this.

How did you use SkyMapper to study Tucana II?
SkyMapper has a specific filter that lets you see purple – we selected near-ultraviolet light around the wavelength of a very strong calcium absorption line near 400nm. The light that we see there is a reflection of how much calcium might be in the star and we can use that as a proxy of its overall chemical content. The less calcium and heavy elements are in that star, the less absorption and the brighter the star will shine when observed with that filter. This is exciting because it means that the stars we are interested in will light up like traffic lights. You may ask why are we looking for low calcium [stars]? The oldest stars in the Universe have the least amount of heavy elements because they formed at a time when not much of that junk had been made yet. Tucana II is around 13 billion years old.

▲ **Clues about the early Universe: by studying dark matter-deficient dwarf galaxies (above), scientists can gain insights into the earliest galactic formation**

What did you find?
Because SkyMapper surveys the entire southern sky, each image is broad. We ran these through our algorithm and out popped seven member stars [of Tucana II] really far out, and we said, 'What's going on?' The stars staggered out to almost 10 times the size of the core. That was surprising, so we had to check our technique and numbers, but we concluded they were all part of the same galaxy. It made us rethink what these small galaxies might be like. This is also the first time that a dark matter halo has been extensively mapped very far away from its galactic centre; it turns out that the entire galaxy is three to five times as massive as previously thought.

What do the stars at Tucana II's edge tell us?
They confirm that Tucana II is really old; the stars further out had a more primitive chemical make-up than those in the core. And that aligns with the theoretical simulation in a follow-up paper that suggests Tucana is the product of a merger of two of the very first galaxies. When you smash galaxies together, chaos ensues and stars get scattered around.

Professor Anna Frebel is an astronomer and Associate Professor of Physics at MIT in Cambridge, Massachusetts

What are your study's implications for our understanding of the early Universe?
It offers up a great, new prospect for people modelling early star formation, early galaxy formation and early element production. The idea of getting the beginning of the story of galaxy formation right, which began a few hundred million years after the Big Bang, is going to be huge! We know what the end is: that's today. So having the beginning right is an important step because then we can interpolate everything in between.

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7.1MP - £2400
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Explore Scientifc 127mm Apo - FROM £1429
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THE SOUTHERN HEMISPHERE

With Glenn Dawes

Catch the Eta Aquariid meteor shower and enjoy a view of the Diamond Cross in Carina, the Keel

When to use this chart

1 May at 00:00 AEST (14:00 UT)
15 May at 23:00 AEST (13:00 UT)
31 May at 22:00 AEST (12:00 UT)

The chart accurately matches the sky on the dates and times shown for Sydney, Australia. The sky is different at other times as the stars crossing it set four minutes earlier each night.

MAY HIGHLIGHTS

Eta Aquariid meteors are known to be swift, yellow and often show persistent trains. The shower's radiant – the point at which it appears to a terrestrial observer – is easily visible from the Southern Hemisphere. In May the radiant rises in the early morning, reaching a reasonable altitude by the start of dawn.

The Eta Aquariid period of activity is from 19 April to 28 May – peaking on the morning of 7 May, which will also have a 25-day-old crescent Moon.

STARS AND CONSTELLATIONS

The constellation of Virgo, the Virgin is home to the Great Diamond asterism, but Carina, the Keel has a much more pleasing (symmetrical) group known as the Diamond Cross. Located between Musca, the Fly and the False Cross asterism, its most northerly star is Theta (θ) Carinae, the brightest member of the cluster known as the Southern Pleiades.

The most prominent member is Beta (β) Carinae. At mag. +1.66 it's the brightest star within 25° of the South Celestial Pole.

THE PLANETS

Presenting a challenge, Mercury and Venus spend May low in the evening twilight. Much better placed is Mars, low in the western evening sky and moving towards the Gemini twin stars of Castor and Pollux. Although of similar brightness, the Red Planet should be easily recognised by its colour. Saturn has now entered the evening sky, rising around 23:00 midmonth, followed by Jupiter around an hour later. Morning arrivals are Neptune (around 02:00 midmonth) and Uranus.

DEEP-SKY OBJECTS

This month we take a deep (sky) dive into the cluster of galaxies in Virgo and Coma Berenices. Starting from the naked-eye star Epsilon (ε) Virginis, move 4.5° west to the pair of 10th magnitude elliptical galaxies M60 (RA 12h 43.7m, dec. +11° 33') and M59 (23' west-northwest of M60). M60 has a bright circular halo (2.5'), brightening towards the centre.

M59 also shows brightening towards the centre, but it's smaller and more oval shaped (2'x1') with a fainter surface brightness. However, this eyepiece field has much more to offer. M60 has a much closer spiral galaxy companion NGC 4647 only 2.5' northwest. At mag. +11.4, it has a fainter, evenly illuminated, circular halo (1'), nearly touching M60's – impressive!

Forming a triangle with M59/60, southward is the elliptical NGC 4638. The smallest of the group, it has a good surface brightness showing off its ovality (1'x0.5').

Chart key

GALAXY
OPEN CLUSTER
GLOBULAR CLUSTER
PLANETARY NEBULA
DIFFUSE NEBULOSITY
DOUBLE STAR
VARIABLE STAR
COMET TRACK
ASTEROID TRACK
METEOR RADIANT
QUASAR
PLANET
STAR BRIGHTNESS:
MAG. 0 & BRIGHTER
MAG. +1
MAG. +2
MAG. +3
MAG. +4 & FAINTER

CHART: PETE LAWRENCE


NORTH
NORTHWEST
WEST
SOUTHWEST
SOUTH
BOÖTES
CANES VENATICI
COMA BERENICES
URSA MAJOR
CORONA BOREALIS
Keystone
Kite
Cor Caroli
Great Diamond
Arcturus
Rasalgethi
Diadem
Sickle
LEO
OPHIUCHUS
SERPENS CAPUT
VIRGO
Leo Triplet
19th
22nd
Regulus
Celestial Equator
M5
M10
M12
M92
M13
M3
M94
M63
M51
M106
NGC 4565
M64
M53
M87
M86
M60
M59
M66
M104
25th
Ecliptic
Spica
LIBRA
CORVUS
CRATER
HYDRA
Alphard
Ghost of Jupiter
Antares
M4
M80
M83
CENTAURUS
ω Cen
M23
M20
M8
M9
M7
28th
SCORPIUS
LUPUS
NORMA
ANTLIA
PYXIS
PUPPIS
VELA
CRUX
Jewel Box
Coal Sack
NGC 3699
CIRCINUS
ARA
CORONA AUSTRALIS
TELESCOPIUM
TRIANGULUM AUSTRALE
MUSCA
Southern Pleiades
Diamond Cross
False Cross
CARINA
"Peacock Star"
APUS
PAVO
OCTANS
CHAMAELEON
Miaplacidus
South Celestial Pole
VOLANS
Tarantula Neb
PICTOR
Canopus
SMC
47 Tuc
HYDRUS
MENSA
LMC
DORADO
TUCANA
RETICULUM